

# **Documentation of Calculation Methodology and Input Data for the Home Energy Saver Web Site**

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## **Abstract**

The Home Energy Saver (HES, <http://HomeEnergySaver.lbl.gov>) is an interactive web site designed to help residential consumers make decisions about energy use in their homes. This report describes the methods and data for estimating energy consumption. Using engineering models, energy consumption is estimated for five major categories (end uses); heating, cooling, major appliances, lighting, and miscellaneous equipment. The approach taken by the Home Energy Saver is to provide users with initial results based on a minimum of user input, allowing progressively greater control in specifying the characteristics of the house and energy consuming appliances. Where information about the house is not available from the user, default values are used based on end-use surveys and engineering studies.

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## 1. Introduction

The Home Energy Saver (HES, <http://HomeEnergySaver.lbl.gov>) is an interactive web site designed to help residential consumers make decisions about energy use in their homes. Its aims are to increase consumer interest in energy efficiency and to foster market activities that capture those opportunities. The site is developed and maintained by the Lawrence Berkeley National Laboratory with sponsorship (past and/or present) from the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and the California Energy Commission.

The HES, which first went on-line in 1996<sup>1</sup>, was originally sponsored by the ENERGY STAR program, operated by EPA and DOE (Mills 1997)<sup>2</sup>. The Home Energy Saver supports the Federal energy mission by helping to build national recognition of Federal energy efficiency programs and by enabling consumers to quantify the energy savings and environmental benefits that can be achieved by improving the energy efficiency of their home. The site is also used periodically by researchers, designers and contractors as a tool for analyzing residential energy performance issues, and for learning from actual homeowners about their experiences with implementing energy-saving upgrades. Finally, through the Energized Learning module, science educators at the high school and college level regularly use HES as part of their science curricula (<http://EnergizedLearning.lbl.gov>). As of late 2003, there are approximately 400,000 top-page visits per year, approximately 80% of which are homeowners or renters, with the balance including building professionals, educators, etc.

In this report, we first provide a brief overview of the process used in estimating residential energy consumption, and then document the calculation methodologies and data assumptions underlying the energy estimation at the appliance level. The report includes an appendix that describes the user interface and software/hardware architecture underlying the site.

## 2. Overview of the Model

The goal in developing the Home Energy Saver web site has been to provide consumers with a simple way to use state-of-the-art energy calculation tools and residential energy data. The site integrates a variety of models, algorithms, and data sources developed over several decades at Lawrence Berkeley National Laboratory, other DOE National Labs, Utilities, and elsewhere in the energy community. Historically, access to and use of such materials has required more extensive expertise and knowledge of energy and building technologies than that possessed by consumers. Making these tools and information available via a web-based interface, enables lay users to obtain energy use and savings estimates tailored to their particular home, climate, lifestyles, etc. While not discussed

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<sup>1</sup> An earlier version developed at LBNL was called WebCalc.

<sup>2</sup> In 2000, the ENERGY STAR program sponsored the development of a simplified consumer web site derived from the HES, called Home Energy Advisor (Advisor, <http://hit.lbl.gov>). In most cases, Advisor uses the same data and calculation methodologies as HES, but employs a more constrained building description and provides different outputs

further here, the site also provides extensive “decision-support” information to accompany the analytical results.

The Home Energy Saver was the first Internet-based tool for calculating energy use in residential buildings. The approach taken by the web site is to provide users with results based on a minimum of user input, and then, for those interested in continuing, allowing them progressively greater degrees of control in specifying the house and energy consuming appliances characteristics. This allows users with limited knowledge or time to access results that are generally applicable to their situation, while more informed or persistent users can get greater accuracy by customizing their house description. This design philosophy results in a progressive three-tiered approach to estimating energy consumption.

At the initial level of inputs, users are asked solely for their zip code (Figure 1). The results presented are averages for the housing stock in their region, based on the 1993 Residential Energy Consumption Survey (RECS). HES also presents potential savings for a typical house in that region.

Simultaneously, users are shown the questions for the second, “simple inputs” level of the Home Energy Saver (Figure 2). This set of questions focuses on those appliances and housing characteristics that cause large variance in energy consumption (e.g. floor area, heating equipment, etc.). These key inputs can be used to refine the energy estimation further.

After answering the questions in the “simple inputs” level of HES, users can either calculate the energy used by their house based on the description provided by the “simple level” of questions or further refine the house description before calculating by accessing the third, “detailed inputs” level of the model. In the detailed input pages, they can adjust nearly all of the house and appliance characteristics that go into estimating energy consumption for their home (Figure 3).

When the user is satisfied with the house description, they calculate the energy consumption, which replaces the results based on a house in their area. At this time they can also view more detailed reports about their home's energy consumption.

For both the “simple inputs” and “detailed inputs” levels, the models used to estimate energy consumption are identical, with user-entered values substituting for default values as the user progresses through the “detailed inputs” level. There are five major categories (end-uses) where energy consumption is estimated; heating, cooling, major appliances, lighting, and miscellaneous equipment. The Home Energy Saver uses engineering models to estimate energy consumption for all these end-uses.

### **Heating and Cooling**

The energy consumption for most types of heating and cooling equipment is estimated using the DOE-2 building simulation program (version 2.1E), developed by the U.S. Department of Energy. The program performs a very sophisticated series of calculations, modeling the energy consumption in the users house in a full annual simulation for a

typical weather year (involving 8760 hourly calculations). Users can choose from 239 weather locations around the United States. The use of DOE-2 for heating and cooling estimation in the Home Energy Saver web site is documented in a companion report (Warner et al. 2004). A few heating and cooling equipment types are estimated independently of DOE-2 and are documented in this report.

### **Water Heating**

Two main types of water heaters are modeled in the Home Energy Saver, separate “stand-alone” units, and cases where the home’s heating system (boiler) provides the domestic hot water supply. When the hot water is supplied by from a boiler, water heating energy is calculated in the DOE-2 building simulation model. All other water heaters are modeled according to the methodology outlined in Section 2-A of this report. For homes with a clothes washer and/or dishwasher, the required gallons of hot water per day is provided as an input to the hot water model (described below) by the clothes washer and dishwasher models.

### **Major Appliances**

Appliances included in the “Major Appliance” category are refrigerators, freezers, clothes washers, clothes dryers, dishwashers, stoves and ovens. Using the number and approximate age of major appliances, the model estimates the energy consumption for appliances, based on historic sales-weighted efficiency data. Section 2-B of this paper contains the energy estimation methodology for each appliance. The estimated consumptions for all appliances are summed to arrive at the “Major Appliance” category totals.

### **Lighting and Miscellaneous Equipment**

The model allows estimation of energy consumption for lighting and dozens of miscellaneous gas and electric appliances, with default values based on data compiled over the years by LBNL researchers.

### **Data**

The Home Energy Saver is dependent upon data from a variety of sources to provide default input values and energy consumption. The bulk of the data compilation for the Home Energy Saver was completed in 1997-1999, and the most current data available at that time was used. For time-sensitive series such as equipment efficiencies, the final data point has been used to provide values for subsequent years. The only exception to this is for the state energy prices, which have been updated to use the most current data available at the time of this report.

## **3. Energy Calculation Models**

### **3.1 Heating and Cooling Calculation**

This report deals with the determination of heating equipment efficiencies, thermal distribution (air or hydronic) efficiencies, infiltration, and thermostat management. A

companion report (Warner 2004) describes the thermodynamic modeling of the home, and the relevant characterizations of the building's thermal envelope (windows, insulation, etc.)

### 3.1.1 Heating and Cooling Equipment

The Home Energy Saver web site models the following heating and cooling equipment types:

**Table 1. Heating and Cooling Equipment**

Equipment Type	Calculation	Default Efficiency	Capacity	Usage
<b>Heating</b>				
Central Gas furnace	DOE-2	78	*	**
Room (through-the-wall) Gas furnace	DOE-2	65.6	*	**
Propane (LPG) furnace	DOE-2	78	*	**
Oil furnace	DOE-2	80	*	**
Electric furnace	DOE-2	98	*	**
Electric heat pump	DOE-2	7.0	*	**
Electric baseboard heater	DOE-2	98	*	**
Gas boiler	DOE-2	80	*	**
Oil boiler	DOE-2	80	*	**
<b>Cooling</b>				
Central air conditioner	DOE-2	9.5	*	**
Room air conditioner	$\frac{\text{capacity} \times \text{hours} \times \text{days}}{\text{efficiency} \times 1000} \times 0.003412$	9.0	13000	Hours=5, Days=99
Electric heat pump	DOE-2	9.5	*	**
Whole house fan	$P_{fan} \times \text{hour} \times 30 \times \text{months}$	$P_{fan}=0.3 \text{ kWh}; \text{hours}=2; \text{months}=2$		
Ceiling fan	$50 \text{ kWh} \times \text{Num}_{fans}$	$\text{Num}_{fans}=2$		
Portable fan	$22 \text{ kWh} \times \text{Num}_{fans}$	$\text{Num}_{fans}=2$		

\* Capacity for this equipment type is autosized in the DOE-2.1 engine.

\*\* Usage for this equipment type is calculated in the DOE-2.1 engine, based on user-specified thermostat settings and schedule (see below)

For those equipment types modeled in DOE-2, the equipment characteristics (default values taken from Table 1), are sent to the DOE-2 model. Energy consumption in million BTUs is returned from DOE-2 and is multiplied by the fuel conversion factors found in Table 2 to arrive at utility units.

**Table 2. Fuel conversion factors**

Fuel	Conversion factor
Electricity	3412.76 kWh/MBtu
Natural Gas	100,000 therms/MBtu

Liquid Propane	91,500 gallons LPG/MBtu
Fuel Oil	138,690 gallons oil/MBtu

In the detailed inputs level of the model, users can select the year their heating and cooling systems were purchased as an alternative to entering an efficiency for the equipment. In these cases, we derive a shipment-weighted efficiency based on the year the equipment was purchased (Table 3 and Table 4). This number is the average efficiency for all units sold within a particular year weighted by the number of units in each efficiency bin (AHAM 1996). Efficiencies for furnaces is measured as AFUE, or Annual Fuel Utilization Efficiency rating, which measures the seasonal or annual efficiency of the furnace. Heat pumps efficiency is shown as HSPF, Heating Seasonal Performance Factor.

**Table 3. Shipment Weighted Efficiencies for Heating Equipment**

<b>Year</b>	<b>Electric Furnace (AFUE)</b>	<b>Electric Heat Pump (HSPF)</b>	<b>Gas Boiler (AFUE)</b>	<b>Gas Furnace (AFUE)</b>	<b>Gas Wall Furnace (AFUE)</b>	<b>Oil Boiler (AFUE)</b>	<b>Oil Furnace (AFUE)</b>	<b>Propane Furnace (AFUE)</b>
1970	98	5.5	70	60	50	72	70	60
1972	98	6.21	72.3	62.7	59.5	75.2	73.6	62.7
1973	98	6.21	72.3	62.7	59.5	75.2	73.6	62.7
1974	98	6.21	72.3	62.7	59.5	75.2	73.6	62.7
1975	98	6.21	72.3	62.7	59.5	75.2	73.6	62.7
1976	98	6.21	72.3	63	59.5	75.2	74.1	63
1977	98	6.21	72.3	63.3	59.5	75.2	74.5	63.3
1978	98	6.21	72.3	63.6	59.5	75.2	75	63.6
1979	98	6.21	72.3	64.8	59.5	75.2	75.5	64.8
1980	98	6.21	72.3	65.9	59.5	75.2	76	65.9
1981	98	6.21	77.4	67.1	63.1	77.4	76.8	67.1
1982	98	6.21	77.4	68.4	63.1	77.4	77.5	68.4
1983	98	6.2	77.4	69.6	63.1	77.4	78.3	69.6
1984	98	6.36	77.4	73	63.1	77.4	78.6	73
1985	98	6.39	77.4	73.8	63.1	77.4	78.6	73.8
1986	98	6.55	78.2	74.3	64.2	81.6	79.6	74.3
1987	98	6.71	78.2	75.1	64.2	81.6	79.8	75.1
1988	98	6.88	78.2	75.8	64.2	81.6	80.4	75.8
1989	98	6.92	79.7	75.5	65.6	83.1	80.4	75.5
1990	98	7.03	79.7	75.7	65.6	83.1	80.3	75.7
1991	98	7.03	79.7	76.9	65.6	83.1	80.8	76.9
1992	98	7.03	79.7	83.2	65.6	83.1	80.8	83.2
1993	98	7.03	79.7	83.8	65.6	83.1	80.9	83.8
1994	98	7.03	79.7	83.9	65.6	83.1	80.9	83.9
1995	98	7.03	79.7	84.1	65.6	83.1	80.9	84.1
1996	98	7.03	79.7	84.1	65.6	83.1	80.9	84.1

Data has been held at 1996 levels for subsequent years.

### Cooling Equipment Efficiencies

The cooling efficiency for Central Air Conditioners and Electric Heat Pumps are rated by the seasonal efficiency of the equipment or SEER. Room Air Conditioners are rated by EER or Energy Efficiency Ratio, the ratio of the cooling output (in BTU) divided by the energy consumption (in watt-hours).

**Table 4. Shipment Weighted Efficiencies for Cooling Equipment**

Year	Central Air Conditioner (SEER)	Electric Heat Pump (SEER)	Room Air Conditioner (EER)
1970	6.5	5.5	5.8
1972	6.66	6.21	5.98
1973	6.68	6.21	6
1974	6.7	6.21	6.1
1975	6.72	6.21	6.2
1976	6.75	6.21	6.4
1977	6.79	6.21	6.55
1978	6.85	6.21	6.72
1979	6.91	6.21	6.85
1980	6.97	6.21	7.02
1981	7.04	6.21	7.06
1982	7.14	6.21	7.14
1983	7.28	6.2	7.29
1984	7.45	6.36	7.48
1985	7.64	6.39	7.7
1986	7.85	6.55	7.8
1987	8.06	6.71	8.06
1988	8.23	6.88	8.23
1989	8.42	6.92	8.48
1990	8.58	7.03	8.73
1991	8.75	7.03	8.8
1992	8.98	7.03	8.88
1993	9.19	7.03	9.05
1994	9.41	7.03	8.97
1995	9.58	7.03	9.03
1996	9.58	7.03	9.08

Data has been held at 1996 levels for subsequent years.

### Room Air Conditioner Consumption:

Room air conditioners tend to be operated not by central thermostatic control, but rather in a manual mode where the room occupant turns the air conditioner on and off depending on room temperature and occupancy. These complex operating patterns are difficult to model with thermal simulation models such as DOE-2. For this reason, we chose to use a simpler method for estimating room air conditioner energy consumption, based on the AHAM (Association of Home Appliance Manufacturers) test procedure. This method is summarized in equation 1.

$$UEC = \frac{Days \times Hours \times Cap}{EER} \quad \text{Equation 1}$$

Where

Days	=	Average annual days of RAC operation (days/year)
Hours	=	Average daily hours of RAC operation (hours/day)
Cap	=	Rated capacity of the room air conditioner (Btu/hour)
EER	=	Energy-efficiency ratio (Btu/kWh)
UEC	=	Unit Energy Consumption (kWh/year)

Because cooling loads and usage vary with climate, we estimated a default *Days* and *Hours* value for each of the cities for which we had a weather tape (Table C-1). We estimated the default daily operating hours using equation 2. These values were rounded to the nearest integer. Climate data used in this equation were drawn from the TMY2 weather tapes. The first term in equation 2 accounts for the severity of the climate, in terms of dry bulb temperature, while the second term accounts for how humid the climate is. Note that the humidity term is assumed to equal zero for locations above 40°N latitude. The parameters in equation 2 were estimated heuristically so as to yield results that looked reasonable across a range of climates.

$$Hours = \frac{2}{5} \times (Temp_{db} - 80) + 20 \times (1.5 - \frac{Temp_{db}}{Temp_{wb}}) \quad \text{Equation 2}$$

Where

Temp <sub>db</sub>	=	Drybulb temperature at cooling design-day conditions (°F)
Temp <sub>wb</sub>	=	Wetbulb temperature at cooling design-day conditions (°F)

We then derived a value for annual RAC compressor hours from the AHAM test procedure manual (AHAM 1982, Appendix B). We used the value corresponding to 66% of full-load, to account for some cycling that occurs in normal room air conditioner operation (Table C-1). Where one of our weather cities was not listed in the AHAM document, the Cooling Load Hour value shown in Table C-1 is extrapolated from the geographically closest city, using the TMY2 cooling-degree hours at 74° F as a scaling factor.

Finally, the average days per year of operation is simply the ratio of annual compressor hours to the average daily hours of operation.

Room air conditioner capacity is either input by the user or a national-average default value is used (12,000 Btu/hour). EER is also either user-entered or drawn from the shipment-weighted average for the year in which the air conditioner was sold (as specified by the user).

### 3.1.2 Thermostats and Thermostat Schedules

The Home Energy Saver is capable of modeling both standard and programmable thermostats. The initial thermostat assigned to a new session is a standard thermostat with

the default schedule and temperature settings outlined in Table 5. Users can adjust the temperature and time schedules for the two periods (day and night), and can specify a separate schedule for weekdays and weekends/holidays.

**Table 5. Default Thermostat Schedule for Standard Thermostats**

<input type="checkbox"/>	Hour	Temperature	
		Heating	Cooling
Day	8:00 AM	68	78
Night	5:00 PM	64	81

Alternatively, users can choose a programmable thermostat, which defaults to the schedule outlined in Table 6. Like with a standard thermostat, users can specify alternate times and temperatures for the four periods, to differentiate between weekday and weekend/holiday schedules.

**Table 6. Default Thermostat Schedule for Program Thermostats**

	Hour	Temperature	
		Heating	Cooling
Wake	7:00 AM	64	78
Leave	9:00 AM	64	78
Evening	7:00 PM	68	81
Sleep	11:00 PM	68	81

The thermostat schedule is sent as an input to the DOE-2 calculation engine where it is used in calculating energy consumption by the heating and cooling equipment.

### 3.1.3 Internal Gains

Anything that gives off heat as a waste product affects the heating and cooling loads within the house. The waste heat causes an increase in the cooling energy consumption, and a decrease in the heating energy consumption. The Home Energy Saver attempts to account for internal gains by passing information about internal heat loads to the DOE-2 building simulation engine. Information about the number of occupants and the energy consumption in kWh for lighting and appliances, including water heater, for all equipment located within the conditioned space is sent as internal gains to DOE-2. This value also reflects waste heat from gas appliances located within the conditioned space, which is converted to kWh for inclusion.

### 3.1.4 Thermal Distribution Efficiency

As documented in a companion report (Warner 2004), the Home Energy Saver uses the DOE-2 thermal simulation model to estimate heating and cooling consumption. The treatment of air distribution duct losses in DOE-2 is very simple, allowing only a single value of duct losses (expressed as a percent of air input to the ducts) that applies to every hour throughout the year. Although it would be desirable to model duct efficiency as varying throughout the year, as a function of the ducts' environmental conditions, this would require a significant effort in modifying DOE-2.

Instead, we used an annual-average method for estimating the effect of duct materials and the type of space in which the majority of their duct system is located, since duct losses

differ significantly depending on these factors. We used the ASHRAE 152P duct model to estimate duct losses for use as an input to DOE-2 (ASHRAE 1997). Although this model is intended to calculate seasonal duct efficiencies based on detailed diagnostic testing, we assumed typical values for most of the inputs (such as duct surface area and number of return ducts) so that the number of inputs required of the user is more reasonable.

Users are able to specify whether or not the ducts are insulated and/or sealed, and the duct location. Insulated ducts are assumed to have R-5 insulation, while uninsulated ducts are assigned an insulation value of R-1 (to account for the thermal resistance of the external air film on the ducts). Unsealed ducts are assumed to have a leakage of 30% of the total air handler flow, based on work conducted by Walker (1998) in existing California homes. Because concerted duct sealing efforts can typically reduce leakage by one-half, we assume that sealed ducts have a leakage rate of 15%. If users choose not to specify their duct location, we infer the location based on the type of foundation and typical building practices. Table 7 shows the default duct location that corresponds to each of the foundation types available in HES.

**Table 7. Default Duct Location**

Foundation Type	Assumed Duct Location
Unconditioned Basement	Unconditioned Basement
Conditioned Basement	Conditioned Space
Ventilated Crawlspace	Ventilated Crawlspace
Unventilated Crawlspace	Unconditioned Basement
Slab-on-grade	Unconditioned Attic

The ASHRAE 152P model generates seasonal duct efficiencies for both the heating and cooling seasons, which are then averaged together using weights corresponding to the HDD and CDD in that location, normalized to the national average degree-days (using TMY2 data). These weighting factors are shown in Table C-1, in the “duct factor” columns. A single annual average duct efficiency is passed to the DOE-2 model as an input to the hourly thermal simulation. This annual duct efficiency is determined based on the type of heating and cooling equipment in the house.

**Table 8. Annual Duct Efficiency based on HVAC equipment**

		Heating Equipment	
		No Ducts	Has Ducts
Cooling Equipment	No Ducts	1.0	HSE
	Has Ducts	CSE	$efficiency_{ducts} = DF * HSE + (1 - DF) * CSE$

Notes:

DF = weight factor based on relative HDD and CDD

HSE = Heating seasonal duct efficiency

CSE = Cooling season duct efficiency

### Boiler Pipe Efficiency

Boiler pipes are assumed to have a baseline efficiency of 90% (Wenzel 1997). Users are able to indicate whether their pipes are insulated. For insulated pipes we stipulate a 5% increase in efficiency.

### 3.1.5 Infiltration

Air infiltration can be a significant component of thermal losses in residential buildings. In the Home Energy Saver, the energy impact of air infiltration is calculated by DOE-2, based on the leakage area of the thermal shell and location-specific weather tapes.

Although leakage area can be measured using diagnostic testing, few homeowners know the leakage area of their home. To compensate for this lack of information, we estimate leakage area using a database of measured leakage values compiled by LBNL. This database has been analyzed to provide average leakage values for single-family homes based on a few key parameters that strongly influence air leakage (Matson 1998). The LBNL leakage database reports leakage values as Normalized Leakage (NL), or square feet of leakage area per 1000 square feet of conditioned floor area. For input to DOE-2, we converted these normalized leakage values to fractional leakage areas (FLA) using equation 3.

$$FLA = \frac{\frac{NL}{1000}}{\frac{8 \times 0.348 \times \text{stories}^{0.3}}{2.5}} \quad \text{Equation 3}$$

where

FLA = fractional leakage area

NL = normalized leakage (sq. ft. leakage/sq. ft. conditioned floor area)

stories = 1 if single-story house, otherwise stories = 2

8 is the assumed ceiling height for the house

The key parameters used to determine a house's leakage are: house vintage (pre-1980, 1980 and later), stories (1, more than 1), shell condition (whether or not air leaks have been sealed in a comprehensive way), presence of a ducted heating or cooling system, and air leakage through the floor (slab or conditioned basement, vs. other foundation types). In addition, for houses built in 1990 or later, we assume a leakage value that is consistent with the "tight" thermal shells typically seen in new construction (NL = 0.5).

### 3.1.6 Combined boilers

For houses where the main heating equipment also provides the hot water, the DOE-2 simulation engine calculates the hot water energy consumption. There are two different types of combined boiler, direct and indirect. Direct combined boilers heat the water upon demand. Indirect combined boilers have a storage tank, similar to a stand-alone hot water heater, which provides hot water upon demand. The boiler maintains a steady temperature within the hot water storage tank.

### 3.1.7 DOE-2 Post-processing

When the DOE-2.1E simulation program executes, it produces a large text output file containing a series of user-specified output reports. We then post-process the raw DOE-2 output file to extract only those results that will be presented to the HES user. These results are drawn from the BEPS, SV-A, SS-A, and PV-A standard reports offered by DOE-2. Table 9 shows which values are drawn from these reports. The post-processor is implemented in the Perl scripting language.

**Table 9. DOE-2.1E Output Reports used in HES**

<b>DOE-2 report</b>	<b>Values used in reporting to user</b>	<b>Units</b>
BEPS	Space heat (all fuels) Space cool Pumps & miscellaneous Supplemental heat (heat pump strip heat) Vent fans	MBtu
SV-A	Heating equipment capacity Cooling equipment capacity	KBtu/hour
SS-A	Annual heating load Annual cooling load Peak heating load Peak cooling load	Mbtu  KBtu/hour
PV-A	Boiler capacity	KBtu/hour

### 3.2 Water Heater Energy Consumption

This module calculates energy consumption for heating water in three steps. The first step is to estimate average daily hot water use. This calculation is based on number and ages of people living in the house, presence or absence of a dishwasher and a clothes washer, the water heater temperature setting and tank size, and the local climate (Lutz, et al, 1996).

Once the average daily hot water use has been estimated, a simple calculation is performed to determine the daily energy use by the water heater. The calculation uses the energy consumption characteristics of the water heater as determined by the DOE Energy Factor test, ambient air and inlet water temperatures, and how much hot water is used on an average day. The last step is to convert the daily energy use into annual consumption of specific fuels, (e.g. electricity and gas).

#### Daily Hot Water Use

The Home Energy Saver web site uses the following equation<sup>3</sup> to estimate average daily hot water use in gallons per day (Lutz, et al. 1996). This equation was modified and improved from Lutz et al's version by subtracting out the constant assumed hot water use of clothes washers and dishwashers (the variables *cloth* and *dish* in Equation 4), and adding two variables (*cwGals* and *dwGals*) that allow users to more accurately specify their clothes washer and dishwasher hot water use (e.g. specifying loads washed at certain temperatures). The calculation of hot water use by clothes washers and dishwashers is described elsewhere in this report.

$$Use_{wh} = 1.78 + 0.9744 \text{ occupants} + 6.3933 \text{ age1} + 10.5178 \text{ age2} + 15.3052 (\text{age3} + \text{age4}) - 0.1277 T_{tank} + 0.1437 \text{ tank\_size} - 0.1794 T_{in} + 0.5115 \text{ average\_temp} + 10.2191 \text{ adult\_at\_home} - \text{dish} - \text{cloth} + \text{cwGals} + \text{dwGals} \quad \text{Equation 4}$$

where

Use<sub>wh</sub> = hot water consumption (gallons/day)  
 occupants = number of persons in household (sum age1-4)  
 age1 = number of people aged 0-5 yrs  
 age2 = number of people aged 6-13 yrs  
 age3 = number of people aged 14-64 yrs  
 age4 = number of people aged 65- yrs  
 T<sub>tank</sub> = water heater thermostat setpoint (°F)

<sup>3</sup> The original development of the water heating analytical method was sponsored by the U.S. Department of Energy, Office of Building Technology, State, and Community Programs as part of their appliance standards analysis program.

tank\_size = rated volume of water heater (gallons)  
 T<sub>in</sub> = inlet water temperature (°F)  
 average\_temp = average annual outdoor air temperature (°F)  
 adult\_at\_home = 1 if TRUE, 0 if FALSE, adult at home during day  
 dish = dishwasher hot water use embedded in original Lutz et al. equation  
 (Lutz, et al. 1996, Equation 12)  
 cloth = clothes washer hot water use embedded in original Lutz et al. equation  
 (Lutz, et al. 1996, Equation 8)  
 cwGals = calculated gallons of hot water used by clothes washer based on  
 user inputs, see Section 3.3.3 [replaces more generic estimation  
 method (cloth)] (gallons/day)  
 dwGals = calculated gallons of hot water used by dishwasher based on user  
 inputs, see Section 3.3.4 [replaces more generic estimation method  
 (dish)] (gallons/day)  
 pay = 1.3625 if residents do not pay for energy to make hot water (to reflect  
 less water-conserving behavior), otherwise pay = 1  
 senior = 0.379 if only seniors live in household and it is a multifamily  
 residence, otherwise senior = 1

### Daily Water Heater Energy Use

To estimate average daily hot water thermal-energy consumption, we use the following equation (Lutz, et al., 1996). T<sub>in</sub> is calculated based on the weather data for the weather station to which the house was assigned, described more fully in section 4.1.

$$Q_{in} = \frac{use_{wh} \cdot dens \cdot Cp \cdot (T_{tank} - T_{in})}{RE} + \frac{UA \cdot (T_{tank} - T_{amb})}{Pon} + 24 \cdot UA \cdot (T_{tank} - T_{amb}) \quad \text{Equation 5}$$

where

Q<sub>in</sub> = hot water consumption (MBtu/day)  
 use<sub>wh</sub> = hot water use per day (gallons) from Equation 1  
 dens = density of water (8.293752 lb/gal)  
 Cp = specific heat of water (1.000743 Btu/lb-°F)  
 T<sub>tank</sub> = water heater thermostat setpoint (°F)  
 T<sub>in</sub> = inlet water temperature (°F)  
 RE = recovery efficiency of water heater  
 UA = standby heat loss coefficient of water heater (Btu/hr-°F) from Eq. 3  
 T<sub>amb</sub> = annual average air temperature around water heater (°F)  
 Pon = rated input power of water heater (Btu/hr)

### Ambient Air Temperature

The average annual air temperature around the water heater (T<sub>am</sub>) is derived from the location of the water heater. If the water heater is located inside conditioned space, T<sub>am</sub> is set to the indoor air temperature (default value of 67.5 °F), if the water heater is located in the basement, T<sub>am</sub> is set to the average of the indoor and outdoor air temperatures (outdoor air temperature taken from the 30-year-average weather tape data for their location, see section 4.1), otherwise T<sub>am</sub> is set to the average outdoor air temperature.

### Standby Heat Loss Coefficient

To calculate the standby heat loss coefficient, we use the equation for heat loss from the DOE Energy Factor test procedure for water heaters, as shown in Equation 6.

$$UA = \frac{\frac{1}{EF} + \frac{1}{RE}}{67.5 + \frac{24}{Q_{out}} + \frac{1}{RE \cdot P_{on}}} \quad \text{Equation 6}$$

where

UA = standby heat loss coefficient (Btu/hr-°F)

EF = Energy factor of water heater

RE = recovery efficiency of water heater

Pon = rated input power of water heater (Btu/hr)

Q<sub>out</sub> = Energy content of water drawn from water heater during 24 hour test

(41093.7 Btu/day)

### Annual Water Heater Energy Use

To estimate average annual hot water energy consumption by type of fuel, we use the following equation.

$$EC_f = 365 \cdot \frac{Q_{in}}{FC} \quad \text{Equation 7}$$

where

EC<sub>f</sub> = annual energy consumption for fuel f

Q<sub>in</sub> = daily water heater thermal-energy use

FC = heat content for fuel f, from Table 1

365 = number of days per year

### User Inputs to the Water Heater Model

At the simple inputs level of the Home Energy Saver, users are asked to select the fuel of their water heater. The water heater characteristics (tank size, year purchased, etc.) are defaulted based on choice of water heater fuel (Table 10). The values for recovery efficiency and rated input for the water heater are derived from manufacturers' product specifications (GAMA 1996) for typical models of each fuel type. Tank size was taken from Table 4.4 of the *Energy Data Sourcebook* (Wenzel 1997).

**Table 10. Default Water Heater Characteristics by Fuel**

Water Heater Fuel	Year Purchased	Energy Factor (%)	Recovery Efficiency (%)	Rated Input Value Units	Tank Size (gal)
Electricity	1986	See Table 3	0.98	4.5 kWh/hr	50
Natural Gas	1986	See Table 3	0.76	38,000 Btu/hr	40
LPG	1986	See Table 3	0.76	38,000 Btu/hr	40
Fuel Oil	1986	See Table 3	0.76	0.65 gal/hr	32

**Energy Factor**

The energy factor for the water heater is a derived shipment-weighted efficiency based on the year the equipment was purchased (Table 11). This number is the average efficiency for all units sold within a particular year weighted by the number of units in each efficiency bin (AHAM 1996). The energy factors for LPG and Fuel Oil fired water heaters were not available, so natural gas energy factors were used for LPG equipment, and Fuel Oil energy factor is 0.54 before 1990 and 0.59 after 1990, based on appliance standards (Lutz, personal communication).

**Table 11. Shipment Weighted Energy Factors for Water Heaters (%)**

Year	Electric	Natural Gas	LPG	Fuel Oil
1972	0.798	0.474	0.474	0.54
1973	0.798	0.474	0.474	0.54
1974	0.798	0.474	0.474	0.54
1975	0.798	0.474	0.474	0.54
1976	0.799	0.475	0.475	0.54
1977	0.799	0.475	0.475	0.54
1978	0.8	0.476	0.476	0.54
1979	0.801	0.476	0.476	0.54
1980	0.802	0.477	0.477	0.54
1981	0.803	0.478	0.478	0.54
1982	0.804	0.479	0.479	0.54
1983	0.806	0.48	0.48	0.54
1984	0.809	0.481	0.481	0.54
1985	0.812	0.483	0.483	0.54
1986	0.815	0.484	0.484	0.54
1987	0.819	0.486	0.486	0.54
1988	0.823	0.488	0.488	0.54
1989	0.828	0.49	0.49	0.54
1990	0.832	0.492	0.492	0.59
1991	0.837	0.494	0.494	0.59
1992	0.842	0.496	0.496	0.59
1993	0.846	0.498	0.498	0.59
1994	0.85	0.499	0.499	0.59
1995	0.854	0.5	0.5	0.59
1996	0.857	0.501	0.501	0.59

Efficiencies have been held at 1996 levels for subsequent years.

### User Inputs for Water Heater Analysis

In the detail screens of the Home Energy Saver, users can modify the water heater characteristics to more closely simulate their equipment and it's usage. Table 12 shows the range of values for the inputs previously mentioned and lists other characteristics (and their range of values) that users can modify.

**Table 12. User Inputs for Water Heaters (Detailed Inputs Level)**

Variable Name	Range of Possible Values	Default Value
Fuel	Electric Natural Gas Liquid Propane Gas (LPG) Fuel Oil	Varies by region (zip code)
Type	Separate Combined boiler, tankless Combined boiler, storage tank	Separate
Pay for Fuel (No if solar)	Yes No	Yes
Adult at Home during weekdays	Yes No	No
Energy Factor	0 – 1.0	See Table 2
Recovery Efficiency	0 – 1.0	See Table 2
Rated Input	0 – 99,000 (kWh, Btu/hr)	See Table 2
Tank Size (gallons)	0 – 500	See Table 2
Thermostat setting	Low (120 °F) Medium-Low (130 °F) Medium (140 °F) Medium-High (150 °F) High (160 °F)	Medium-Low (130 °F)
Location	Basement or Crawlspace Garage Indoors Outdoors	Varies by foundation type

### 3.3 Major Appliances

#### 3.3.1 Refrigerator Energy Consumption

Refrigerators can have very different energy consumption depending on the year of manufacture and features that affect energy use like size, automatic defrost, or side-by-side design. To estimate the energy consumption of these appliances, we use the calculation method described in the *Energy Data Sourcebook* (Wenzel et al. 1997). Due to changes in technology and Federal efficiency standards, refrigerators have become significantly more efficient over time. Because most consumers do not know the Energy Factor of their refrigerator(s), we use a shipment-weighted energy factor based on the year the refrigerator was purchased (Table 13). This number is the average energy factor for all units sold within a particular year weighted by the number of units in each efficiency bin (AHAM 1996). Note that for purposes of this model, all refrigerators are assumed to be combined refrigerator/freezers.

$$EC = \frac{(365 \times AV)}{EF} \quad \text{Equation 8}$$

where

EC = Annual energy consumption (kWh/year)

AV = Adjusted volume (cubic feet)

EF = Energy Factor (kWh/cubic feet•year)

The refrigerator/freezer adjusted volume is intended to capture in a single parameter the relative energy intensity of the refrigerator's cold and frozen food compartments.

Equation 9 is used to calculate adjusted volume (US DOE 1995)

$$AV = size \times (frac + (1 - frac) \times 1.63) \quad \text{Equation 9}$$

where

AV = Adjusted volume (cubic feet)

size = "Nominal" refrigerator/freezer volume (cubic feet)

frac = Fraction of refrigerator volume devoted to fresh-food storage

For side-by-side refrigerators a fresh-food fraction of 0.6 is used, while all other configurations use a fraction of 0.66 as the fresh food fraction. Note that this model does not account for refrigerator usage factors that might vary between units, such as refrigerator and freezer temperature settings, door opening frequency, food loading rates, and ambient temperatures. While these factors can have a large impact on energy consumption, their effect has not been quantified in a way that could be incorporated into a parametric model such as this.

### User Inputs to the Refrigerator Model

At the simple inputs level, users can specify the number of refrigerators in their house, from zero to three refrigerators. Each refrigerator specified has default characteristics (appliance type, size and year) assigned depending on whether it is the first, second or third refrigerator in the house (Table 14). In the “full” calculation mode, users can alter these default characteristics.

**Table 13. Shipment Weighted Energy Factors for Refrigerators**

Year	General	Automatic defrost		Manual Defrost
		Side-by-Side	Top Freezer	
1972	3.84	3.57	3.56	6.69
1973	4.03	3.81	3.81	6.77
1974	4.22	4.05	4.06	6.85
1975	4.41	4.29	4.31	6.93
1976	4.6	4.53	4.56	7.01
1977	4.79	4.77	4.81	7.09
1978	4.96	5.02	4.75	7.18
1979	5.27	5.32	5.21	7.25
1980	5.59	5.62	5.67	7.32
1981	6.09	5.93	6.12	7.39
1982	6.12	6.02	6.3	7.69
1983	6.39	6.1	6.47	7.98
1984	6.57	6.12	6.75	8.19
1985	6.72	6.36	6.89	5.85
1986	6.83	6.49	6.95	6.14
1987	7.45	7.28	7.66	5.45
1988	7.6	7.45	7.83	5.09
1989	7.78	7.68	8.06	4.55
1990	8.15	7.78	8.51	4.84
1991	8.44	8.26	8.91	4.32
1992	8.8	8.69	9.36	3.5
1993	11.13	12.18	11.39	3.89
1994	11.19	12.45	11.37	4.13
1995	11.22	12.41	11.47	3.75
1996	11.22	12.08	11.48	4.21

Efficiencies have been held at 1996 levels for subsequent years.

Energy Factor has units of (kWh/cubic feet•year).

**Table 14. User Inputs for Refrigerator Analysis**

Variable Name	Range of possible Values	Default Value	unit	Source
Type	General Automatic Defrost, Side-by-Side Automatic Defrost, Top Freezer Manual Defrost	General		
Year	1972-2002	1990 (1 <sup>st</sup> unit) 1983 (2 <sup>nd</sup> unit) 1972 (3 <sup>rd</sup> unit)		
Size	Small (13-15 cu ft) Medium (16-18 cu ft) Large (19-21 cu ft) Extra-Large (22+ cu ft)	20 (1 <sup>st</sup> unit) 17 (2 <sup>nd</sup> unit) 14 (3 <sup>rd</sup> unit)	cu. Feet	

1 Users can specify zero to three refrigerators at the "simple inputs" calculation level.

2. For calculating adjusted volume, the mid-range of each size bin is used, with the exception of the "Extra-Large" bin which uses 24 cu. ft as the calculation value.

### 3.3.2 Freezer Energy Consumption

Freezer energy consumption is driven by many factors such as design (e.g. upright freezers versus chest freezers) and technology (automatic vs. manual defrost capability). Additionally, over the years, freezers have increased in size, causing the overall energy consumption to increase. To estimate the energy consumption of these appliances, we use the calculation method described in the *Energy Data Sourcebook* (Wenzel et al. 1997). Because most consumers do not know the Energy Factor of their freezer(s), we use a shipment-weighted energy factor based on the year the freezer was purchased (Table 15). This number is the average energy factor for all units sold within a particular year weighted by the number of units in each efficiency bin (AHAM 1996). Note that for purposes of this model, all freezers are assumed to be stand-alone units (no fresh food compartment).

$$EC = \frac{(365 \times AV)}{EF} \quad \text{Equation 10}$$

where

EC = Annual energy consumption (kWh/year)

AV = Adjusted volume (cubic feet)

EF = Energy Factor (kWh/cubic feet•year)

The adjusted volume is intended to capture in a single parameter the relative energy intensity of the freezer's frozen food compartments. Equation 11 is used to calculate adjusted volume (US DOE 1995).

$$AV = size \times 1.73 \quad \text{Equation 11}$$

where

AV = Adjusted volume (cubic feet)

Size = "Nominal" freezer volume (cubic feet)

Note that this model does not account for freezer usage factors that might vary between units, such as temperature settings, door opening frequency, food loading rates, and ambient temperatures. While these factors can have a large impact on energy consumption, their effect has not been quantified in a way that could be incorporated into a parametric model such as this.

#### User Inputs to the Freezer Model

In the simple inputs level, users can specify the number of freezers in their house, from zero to two units. Each freezer specified has default characteristics (appliance type, size and year) assigned depending on whether it is the first or second freezer in the house (Table 16). In the detailed inputs level, users can alter these default characteristics.

**Table 15. Shipment Weighted Energy Factors for Freezers**

Year	General	Upright Design		Chest Freezers
		Automatic Defrost	Manual Defrost	
1972	7.29	5.23	7.65	8.78
1973	7.72	5.43	7.93	9.27
1974	8.15	5.63	8.21	9.76
1975	8.58	5.83	8.49	10.25
1976	9.01	6.03	8.76	10.74
1977	9.44	6.23	9.03	11.23
1978	9.92	6.41	9.31	11.74
1979	10.39	6.95	9.84	11.77
1980	10.85	7.49	10.37	11.8
1981	11.13	8.03	10.89	11.82
1982	11.28	8.23	11.38	11.87
1983	11.36	8.43	11.44	11.91
1984	11.6	8.58	11.51	12.31
1985	11.55	9.5	11.56	12.04
1986	12.07	9.44	12.07	12.84
1987	12.93	9.57	12.6	14.41
1988	12.91	9.31	12.61	14.46
1989	13.89	9.47	13.86	15.48
1990	14.19	10.41	14.15	15.67
1991	14.17	10.43	13.95	15.92
1992	13.95	10.38	13.73	15.63
1993	17.38	13.65	17.3	19.43
1994	16.91	13.14	17.02	18.89
1995	16.57	13.16	16.95	18.28
1996	16.56	13.11	17.09	18.18

Data has been held at 1996 levels for subsequent years.

Energy Factor has units of (kWh/cubic feet•year).

**Table 16. User Inputs to the Freezer Analysis**

Variable Name	Range of possible Values	Default Value	unit
Type	General Upright, Automatic Defrost Upright, Manual Defrost Chest Freezer	General	
Year	1972-2002	1990 (1 <sup>st</sup> unit) 1983 (2 <sup>nd</sup> unit)	
Size	Small (13-15 cu ft) Medium (16-18 cu ft) Large (19-21 cu ft) Extra-Large (22+ cu ft)	Medium (1 <sup>st</sup> unit) Small (2 <sup>nd</sup> unit)	cu. Feet

### 3.3.3 Clothes Washer Energy Consumption

Although clothes washers consume energy for both mechanical activities and water heating energy, the majority of the energy used is for water heating. Both machine energy and water heating energy are directly dependent upon the number of loads washed. To estimate the energy consumption of these appliances, Equations 12 and 13 use the calculation method described in the Energy Data Sourcebook (Wenzel et al. 1997). Equation 14 calculates the water heating portion of the total clothes washer energy.

$$EC = ME + WE$$

**Equation 12**

where

EC = Annual energy consumption in utility units

ME = Machine energy (kWh/year)

WE = Water heating energy in utility units (returned from water heater)

When ME and WE are in different units (e.g. for non-electric water heaters) the energy consumption for the clothes washer is calculated and stored separately for both fuels (e.g. 126 kWh and 23 therms).

#### Calculating Machine Energy

The machine energy is the electrical energy consumed by all the physical processes necessary to run a load of laundry (e.g. agitation, spin cycle), and is calculated using Equation 13.

$$ME = LE \times \text{loads} \times 52$$

**Equation 13**

where

LE = load energy (kWh/load)

loads = clothes washer loads / week

52 is weeks/year

Machine energy for the average new clothes washer has not changed significantly over time, so is assumed to be 0.27 kWh / load for the purposes of this model (DOE 1990, Page 3-22 table 3.17).

#### Calculating Water Heating Energy from Clothes Washer Use

The gallons of hot water used by the clothes washer is sent to the water heating model, which calculates the energy consumed by the water heater to supply this amount of hot water to the clothes washer. The daily usage (gallons) attributable to the clothes washer is calculated according to Equation 14 (Koomey et al. 1994).

$$use_{day} = \frac{(\text{loads}_{week} \times use_{load})}{7}$$

**Equation 14**

where

Use<sub>day</sub> = hot water use (gallons/day),

Loads<sub>week</sub> = number of loads per week,

Use<sub>load</sub> = hot water use for the average load (gallons/load)

7 is days per week

Energy consumed by the hot water heater in providing the necessary gallons of hot water for the clothes washer is calculated by the water heating model (see Section 3.2) and incorporated into Equation 12 to arrive at the total energy consumption for the clothes washer.

### User Inputs to the Clothes Washer Model

At the simple inputs level in the Home Energy Saver, users only indicate whether or not a clothes washer is present in their house. A default value for the clothes washer contribution to gallons of hot water per day is set for those houses with clothes washer.

For the detailed inputs level, the number of clothes washer loads is assumed to be 380 loads/year (US DOE 1990) and gallons of hot water per load depends on the temperature setting for the load (Lutz et al. 1996). The default distribution of clothes washer temperature settings was based on our judgment about typical usage patterns. Users can customize the number of loads washed and the temperature settings to match the usage patterns in their house.

**Table 17. Default values for calculating clothes washer gallons**

	Use <sub>day</sub> (gallons/day)	Loads <sub>week</sub>	Temperature (wash/rinse)	Use <sub>load</sub>	Source
Simple Level	8.2	-	-	-	(Koomey et al. 1994) Table 4
Detailed Inputs Level	9.1	2	Hot/Warm	32	(Lutz et al. 1996) Table 1
	0.0	0	Hot/Cold	20	
	9.4	3	Warm/Warm	22	
	2.9	2	Warm/Cold	10	
total	21.4	7			

### 3.3.4 Clothes Dryer Energy Consumption

Clothes dryers consume energy for both mechanical activities and the drying process. The majority of the energy used is for drying. Both machine energy and drying energy are directly dependent upon the number of loads dried. To estimate the energy consumption of these appliances, Equations 15 and 16 use the calculation method described in the *Energy Data Sourcebook* (Wenzel et al. 1997).

$$EC_f = ME + DE \quad \text{Equation 15}$$

where

$EC_f$  = Annual energy consumption for fuel f

ME = Machine energy (kWh/year)

DE = Drying energy in utility units (kWh/year or therms/year)

Energy consumption is portrayed in “utility units” for each fuel type; the electric utility is kWh, natural gas utility unit is the therm,

#### Machine Energy

The machine energy includes the energy consumed by all the mechanical and electrical processes necessary to dry a load of laundry (e.g. drum rotation, timers etc.). Equation 16 is used to calculate the machine energy.

$$ME = LE \times loads_{week} \times 52 \quad \text{Equation 16}$$

where

LE = load energy (kWh)

$loads_{week}$  = clothes dryer loads / week

52 is weeks/year

Machine energy for the average new clothes dryer has not changed significantly over time, so is assumed to be 0.23 kWh / load for the purposes of this model (PG&E 1995).

#### Drying Energy

The energy consumed by the clothes dryer to produce heat necessary to dry the clothing is called the drying energy. The drying energy is calculated according to Equation 17.

$$DE = loads_{week} \times use_{load} \times 52 \quad \text{Equation 17}$$

where

$Loads_{week}$  = number of loads per week,

$Use_{load}$  = drying energy consumption per load (kWh or therms)

52 is weeks per year

The Home Energy Saver models electric and gas clothes dryers. Electric clothes dryers use 3.8 kWh for drying energy for each load of clothing dried. Gas clothes dryers use 0.22 therms per load (PG&E 1995). We do not distinguish between models that have moisture-sensor termination and those that do not.

### **User Inputs to the Clothes Dryer Model**

The method of estimating clothes dryer energy depends on the user inputs available for each of the different levels of user inputs. At the simple inputs level in the Home Energy Saver, there are no user inputs available concerning the clothes dryer. An electric clothes dryer is assigned to the house if users indicate that they have a clothes washer. The number of loads dried is assumed to be equal to the number of loads of laundry washed.

For the detailed inputs level of the Home Energy Saver, the initial number of clothes dryer loads is assumed to be 380 loads/year (US DOE 1990). The default fuel selected for the clothes dryer is electricity. Users can customize the number of loads dried and select the primary fuel used for providing heat.

### 3.3.5 Dishwasher Energy Consumption

Dishwashers consume energy for both mechanical activities and water heating, with the majority of the energy used is for water heating. Both machine energy and water heating energy are directly dependent upon the number of loads washed. To estimate the energy consumption of these appliances, Equations 18 and 19 use the calculation method described in the *Energy Data Sourcebook* (Wenzel et al. 1997).

$$EC = ME + WE$$

**Equation 18**

where

EC = Annual energy consumption in utility units

ME = Machine energy (kWh/year)

WE = Water heating energy in utility units (returned from water heater)

When ME and WE are in different units (e.g. for non-electric water heaters) the energy consumption for the dishwasher will use more than one fuel (e.g. 126 kWh and 23 therms).

#### Machine Energy

The machine energy includes the energy consumed by all the physical processes necessary to run a load of dishes (e.g. pumps, heating element for drying cycle). Equation 19 is used to calculate the machine energy.

$$ME = LE \times \text{loads} \times 52$$

**Equation 19**

where

LE = load energy (kWh/load)

loads = dishwasher loads / week

52 is weeks/year

In the Home Energy Saver, machine energy for dishwashers is assumed to be 0.78 kWh / load for the purposes of this model (US DOE 1990, Page 3-8 table 3.4).

#### Water Heating Energy

The gallons of hot water used by the dishwasher is sent to the water heating model, which calculates the energy consumed to supply this amount of hot water to the dishwasher. The daily hot water usage (gallons) attributable to the dishwasher is calculated according to Equation 20 (Koomey et al. 1994).

$$use_{day} = \frac{(\text{loads}_{week} \times use_{load})}{7}$$

**Equation 20**

where

Use<sub>day</sub> = hot water use (gallons/day),

Loads<sub>week</sub> = number of loads per week,

Use<sub>load</sub> = hot water user per average load (gallons/load)

7 is days per week

Energy consumed by the hot water heater in providing the necessary gallons of hot water for the dishwasher is calculated by the water heating model (see Section 3.2) and incorporated into Equation 18 to arrive at the total energy consumption for the dishwasher.

### User Inputs to the Dishwasher Models

At the simple inputs level, users are unable even to indicate whether or not a dishwasher is present in their house. A dishwasher is assigned to the house if the user indicates that they own a clothes washer. The default value for the dishwasher contribution to gallons of hot water per day is set at the time of dishwasher assignment.

For the detailed inputs level, the number of dishwasher loads is initially defaulted to 208 loads/year (US DOE 1990) with a hot water usage of 11 gallons per load (Lutz et al. 1996). Users can customize the presence of a dishwasher and the number of loads washed per week.

**Table 18. Default values for calculating dishwasher gallons**

	Use <sub>day</sub> (gallons/day)	Loads <sub>week</sub>	Use <sub>load</sub>	Load Energy (kWh/load)
Simple inputs	3.4 <sup>a</sup>	-	-	0.78 <sup>b</sup>
Detailed inputs	6.3	4 <sup>a</sup>	11 <sup>c</sup>	0.78 <sup>b</sup>

Notes:

<sup>a</sup> (Koomey et al. 1994) Table 4

<sup>b</sup> DOE 1990, page 3-8 Table 3.4

<sup>c</sup> (Lutz, et al. 1996) Table 4

### 3.3.6 Stove and Oven Energy Consumption

#### Stove Energy Consumption

In the Home Energy Saver, users are allowed to select between electric and gas stoves. Equation 21 describes the method used to calculate energy consumption by electric stoves. Equation 22 is used with gas stoves.

$$EC = power \times usage_{day} \times 365 \quad \text{Equation 21}$$

where

EC = Annual energy consumption in kWh  
power = energy consumed by stove (kWh/hour)  
usage<sub>day</sub> = hours of use per day for all burners combined  
365 is days per year

For electric ranges, the power consumed is assumed to be 1 kW for the purposes of this model (PG&E 1995).

$$EC = (burner\_rate \times usage_{day} \times 365) + pilotLight \quad \text{Equation 22}$$

where

EC = Annual energy consumption in therms  
burner\_rate = energy consumed by stove (therms/hour)  
usage<sub>day</sub> = hours of use per day for all burners combined  
365 is days per year  
pilotLight = energy consumed by the pilot light (therms/year)

For gas ranges, the power consumed is assumed to be 0.09 therms/hour and pilotLight consumption is 17 therms/year (PG&E 1995). The usage per day is assumed to be 1 hour per day for both electric and gas ranges.

#### Oven Energy Consumption

In the Home Energy Saver, users are allowed to select either an electric and gas oven. Equation 23 describes the method used to calculate energy consumption by electric ovens. Equation 24 is used with gas ovens.

$$EC = power \times usage_{week} \times 52 \quad \text{Equation 23}$$

where

EC = Annual energy consumption in kWh  
power = energy consumed by oven (kWh/hour)  
usage<sub>week</sub> = hours of use per week for the oven  
52 is weeks per year

For electric ovens, the power consumed is assumed to be 2.3 kWh/hour [or 2.3 kW] for the purposes of this model (PG&E 1995).

$$EC = (oven\_rate \times usage_{week} \times 52) + pilotLight \quad \text{Equation 24}$$

where

EC = Annual energy consumption in therms

oven\_rate = energy consumed by stove (therms/hour)

usage<sub>week</sub> = hours of use per week for all burners combined

52 is weeks per year

pilotLight = energy consumed by the pilot light (therms/year)

For gas ovens, the power consumed is assumed to be 0.11 therms/hour and pilotLight consumption is 17 therms/year (PG&E 1995). The usage for all ovens is assumed to be 2 hours per week, regardless of oven fuel.

### User Inputs to the Stove and Oven Model

Users are able to alter the inputs for stoves and ovens only in the detailed inputs model of the Home Energy Saver. Table 19 details the initial assumptions used for calculating stove and oven energy.

**Table 19. User Inputs for Stoves and Ovens**

Variable Name	Range of possible Values	Default Value	unit
<b>Stoves</b>			
StoveFuel	Electric Gas	Electric	
Usage	0 – 10 hours	1	Hours/day
<b>Ovens</b>			
OvenFuel	Electric Gas	Electric	
Usage	0 – 10 hours	2	Hours/week

### 3.4 Miscellaneous Equipment Energy Consumption

#### Methodology

The miscellaneous appliance category contains a varied assortment of small and/or unusual devices that could occur in a house. They are divided into several main categories; Entertainment, Home Office, Miscellaneous Kitchen Appliances, Hot Tubs and Spas, and Other Appliances. The Home Energy Saver bases the energy consumed by miscellaneous equipment on the presence of the equipment in the house, and the typical annual energy consumption for each equipment type (Sanchez 1998). We selected the default set of miscellaneous equipment types present in a house by examining the national saturation for each type. Those devices for which Sanchez (1998) estimated a national saturation greater than 80% were selected as part of the default set for all houses.

At the detailed inputs level, users can add and remove specific miscellaneous equipment types from the default set. In addition, some equipment types vary widely in annual energy consumption with changes in usage patterns. For these equipment types, annual energy consumption was calculated based on user inputs for usage. Table 20 lists the equipment types present in the Home Energy Saver, showing annual energy consumption, the equation used to calculate consumption where applicable, the default usage assumption and whether an equipment type is included in the default set for all houses.

**Table 20. Default Energy Consumptions and Characteristics for Misc. Equipment**

Present in default house?	Miscellaneous Equip.	Annual Energy consumption	Units
<b>Small Kitchen Equip.</b>			
yes	Hot or Cold Bottled Water	300	kWh
	Broiler	73	kWh
	Drip Coffee Machine	301	kWh
	Percolator Coffee Pot	139	kWh
	Deep Fryer	20	kWh
	Electric Fry Pan	84	kWh
	Espresso Machine	19	kWh
yes	Instant Hot Water	160	kWh
	Microwave Oven	120	kWh
	Slow Cooker	139	kWh
yes	Toaster	50	kWh
	Toaster Oven	210	kWh
	Trash Compactor	50	kWh
<b>Home Care</b>			
yes	Cordless vacuum	44	kWh
	Canister Vacuum Cleaner	39	kWh
	Upright Vacuum Cleaner	14	kWh
<b>Consumer Electronics</b>			
yes	Answering Machine	44	kWh
	Audio System		

	small system, low usage	7	kWh
	small system, high usage	22	kWh
	large system, low usage	37	kWh
yes	large system, high usage	110	kWh
yes	Cable Box	168	kWh
yes	Color TV	$(\text{power} * \text{tv\_hrs} * 365) / 1000$	kWh
	power	100	watts
	total hours/day	7	hrs
yes	Computer	25	kWh
	Printer		
	Dot Matrix	115	kWh
	Laserjet	466	kWh
yes	Inkjet	28	kWh
	Home Copier	standby + (power * hours)	kWh
	power	0.15	kWh
	hours/day	0	hours
	standby losses	144	kWh
	Home Fax Machine	134	kWh
	Satellite Dish	96	kWh
yes	VCR	158	kWh
yes	Video Game	49	kWh
<b>Pools and Pumps</b>			
	Pool Pump	$\text{power} * \text{Pool\_hrs} * \text{Pool\_months} * 30$	kWh
	power	2.25	kWh
	hours/day	0	
	months/year	0	
	Pool Heater	215	kWh
	Spa/Hot Tub	Electricity	Gas
	Electric (on 24 hrs/day)	2300 kWh	0
	Electric (on demand)	$5.5 \text{ kWh} * \text{Spa\_hrs} * 52$	0
	Gas spa (on 24 hrs/day)	0	103 therms
	Gas spa (on demand)	0	$1.5 \text{ therms} * \text{Spa\_hrs} * 52$
	Spa Type	none	
	hours/week	0	
	Sump/Sewage Pump	40	kWh
	Well Pump	400	kWh
<b>Miscellaneous Electrical Uses</b>			
	Aquariums	548	kWh
	Automobile Block Heater	250	kWh
yes	Doorbell	120	kWh
	Electric Blanket	44	kWh
	Electric Grill	180	kWh
	Garage Door Opener	53	kWh
yes	Hair Dryer	40	kWh

Heat Tape	100	kWh
Iron Pipe and Gutter		
Heaters	53	kWh
Waterbed Heater	100	kWh
Dehumidifier	900	kWh
Humidifier	400	kWh
Electronic Air Cleaner	166	kWh
	100	kWh
<b>Miscellaneous Gas Appliances</b>		
Gas Fireplace	60	therms
Gas Fireplace with		
Ceramic Logs	80	therms
Gas Grill	30	therms
Gas Lighting	19	therms

### 3.5 Lighting Energy Consumption

Accurately estimating the energy consumption of lighting requires detailed information about the technical details of the fixture and the typical usage pattern for that fixture. Since not all consumers are willing and able to provide that level of detail, the Home Energy Saver offers a means to arrive at lighting consumption with minimal user input as well as a more complete calculation model. In this model, lighting fixtures are grouped according to the room they are located in. Equation 25 calculates the lighting energy consumption for all fixtures in a room. Lighting consumption at the household level is simply the sum of energy consumed by all rooms.

$$EC = \sum_{i=1}^n FE_i \quad \text{Equation 25}$$

where

EC = Annual lighting energy consumption by room (kWh/year)

FE = Fixture energy (kWh/year)

n = number of fixtures in room

The fixture energy represents the energy consumption of both the lamp and ballast components of a light fixture. For the purposes of this model a fixture consists of all the lamps controlled on a single circuit. Fixture Energy is calculated using Equation 26.

$$FE = \left( \frac{P_{lamp} + P_{ballast}}{1000} \right) \times usage \times 365 \quad \text{Equation 26}$$

where

$P_{lamp}$  = combined power for all lamps in fixture (Watts)

$P_{ballast}$  = total ballast power for fluorescent fixtures (Watts)

usage = fixture usage (hours/day)

365 is days per year

Note that ballast energy is only applicable for fluorescent tube fixtures. Any ballast energy for compact fluorescent fixtures and halogen fixtures is assumed to be captured in the total lamp wattage for the fixture.

$$P_{ballast} = 130 \times \left\lceil \frac{NL}{2} \right\rceil \quad \text{Equation 27}$$

where

130 = Ballast power (Watts)

NL = number of lamps in fixture

[Note (NL/2) is rounded to next-higher integer value]

### User Inputs to the Model

At the simple inputs level of modeling, users are asked to specify the number of fixtures per room. The model then estimates the energy consumption per room, using default values based on the appropriate room (Table 21), derived from a Tacoma Public Utilities Study (Jennings et al. 1997; Tribwell and Lerman 1996). Where these default data are used, all fixtures in the room are considered to be identical. Alternatively, at the detailed inputs level of modeling, users are able to enter lamp type, number of lamps/fixture, total fixture wattage and usage individually for every fixture.

**Table 21. Default Lighting inputs**

Room	Lamp Type	Number of Lamps	Ave. Lamp Wattage	Ave. Fixture Wattage	Usage (hr/day)	Annual UEC by Room
Kitchen	Incandescent	2	59.17	95.13	3	218
Dining Room	Incandescent	3	62.47	165.03	2	136
Living Room	Incandescent	1	98.24	123.61	2	109
Family Room	Incandescent	1	73.42	106.22	2	77
Master Bedroom	Incandescent	1	67.83	92.73	1	81
Bedroom	Incandescent	1	68.32	94.11	1	73
Closet	Incandescent	1	60.04	65.68	1	0
Bath	Incandescent	2	70.47	138.29	2	192
Hall	Incandescent	1	65.02	78.05	2	98
Utility	Incandescent	1	61.61	83.57	2	0
Garage	Incandescent	1	75.09	102.88	2	71
Outdoor	Incandescent	1	83.63	110.02	3	231
Other	Incandescent	1	71.79	102.76	1	0

Notes:

- 1) Number of lamps derived from average Lamp and Fixture wattages.
- 2) Available lamp types are Incandescent, Halogen Torchier, Compact Fluorescent and Fluorescent tubes
- 3) Allowable usage is from 0 to 24 hours/day

## 4. Data

### 4.1 Weather Data

For modeling climate-sensitive end-uses (space heating, space cooling, and water heating), we use weather data in the Typical Meteorological Year (TMY) format. This includes 239 weather stations in the U.S. and its territories from the U.S. DOE's TMY2 data set (Marion and Urban 1995), plus an additional 10 weather stations in California from the California Energy Commission's CTZ data set.

At the simple inputs level of the Home Energy Saver, users are assigned the weather station that has the most similar climate to the ZIP code that they enter. Climatic "proximity" is determined by comparing the annual heating degree-days (HDD) and cooling degree-hours (CDH) for the user's ZIP code and a given weather station, using equation 28. The most similar climate is that which minimizes  $\Delta_{climate}$ . For the weather stations, annual HDD and CDD are drawn from the pre-processed summary statistics that are published as part of the TMY2 weather tapes. For the ZIP codes, climate data are drawn from the analysis of DOE recommended insulation levels (Stovall 1997, ORNL 1997). Because the two data sets did not offer the same climate indicators (degree-days vs. degree-hours), we normalized the climate indicators to the national average for that data set, to allow comparison of relative climate intensities. For example, the  $HDD_{WT}$  values used in equation 29 were the "raw" values from the weather tapes divided by the average  $HDD_{WT}$  over all weather tapes, thus representing an index of heating intensity.

$$\Delta_{climate} = \sqrt{\left((HDD_{WT} - HDD_{ZIP})^2 + (CDD_{WT} - CDD_{ZIP})^2\right)} \quad \text{Equation 28}$$

where

- $\Delta_{climate}$  = the climatic "distance" between a weather station and ZIP code
- $HDD_{WT}$  = normalized annual heating degree-days (base 65°F) for weather station
- $HDD_{ZIP}$  = normalized annual heating degree-days (base 65°F) for ZIP code
- $CDD_{WT}$  = normalized annual cooling degree-days (base 65°F) for weather station
- $CDH_{ZIP}$  = normalized annual cooling degree-hours (base 74°F) for ZIP code

The ZIP-code climate data from the ORNL analysis are at the three-digit ZIP code level. In many cases these three-digit ZIP codes cover non-contiguous geographic areas, which can lead to incorrect or ambiguous weather station assignments when the climate varies significantly within the ZIP code area. To minimize these problems, we manually reviewed the assignments that were generated using equation 28, by visually comparing maps, and modified assignments that seemed incorrect.

For use in modeling water heating energy consumption, we estimate the annual average inlet water temperature (from the domestic water system) by subtracting 2°F from the annual average dry-bulb air temperature reported in the TMY2 weather tapes.

Summary weather statistics for each TMY2 tape were calculated using the DOE-2 weather packing routines. These summary statistics include seasonal heating and cooling degree-days, winter and summer design-day conditions, and weather-station location data. DOE-2 utilizes the full TMY2 weather tape, extracting insolation data and other needed information for use in the annual simulation.

#### **4.2 Default House Characteristics**

To assist users with describing the characteristics of their house, when users first enter the Home Energy Saver site, they are assigned default house characteristics based on the Census Division in which their ZIP code is located. These default characteristics were developed by analyzing the 1993 Residential Energy Consumption Survey (RECS) microdata (US DOE 1995a). Where a house characteristic can only have discrete values (e.g., type of heating fuel or presence of dishwasher), we tabulated the saturation of that characteristic in the RECS data set and selected the most common value. For example, if natural gas was the most common heating fuel in a region, then the default house is assumed to use natural gas for heating. Appendix A. Table A-1 contains the default input values for each census division. For the remaining characteristics for the house, a single value was applied across all divisions. Appendix A. Table A-2 contains these nation-wide default housing characteristics. Default house shell characteristics, for use in DOE-2 are described in the DOE-2 companion report (Warner, 2004).

#### **4.3 Average Energy Bills for Existing Houses**

In order to provide users an initial estimate of energy savings potential in their house, we estimated average energy bills by climate region from the sample of single-family housing units (including manufactured homes) in the 1993 RECS microdata (US DOE 1995a). Energy bills by end-use were based on the end-use consumption estimates reported in the RECS microdata. For each housing unit in the RECS sample, EIA reports the Census Division in which that housing unit is located, as well as summary climate data (HDD and CDD) from the geographically closest weather station.

In order to provide finer geographic disaggregation of the RECS data, we assigned each of the RECS housing units to one of 45 climate regions in the U.S. These climate regions were originally developed by LBNL for the PEAR energy analysis program (Huang et al. 1987). The climate region assignment used a climate-distance method similar to equation 29, comparing the climate data reported for each RECS housing unit to TMY2 climate data for a representative city in each climate region. Using these climate-region assignments, within each climate region we selected those single-family housing units that had the most common heating and cooling characteristics (heating fuel, water heating fuel, and presence of central air conditioner) for that region. We determined the most common characteristics through the default house analysis described in the previous section. These characteristics, and the number of RECS records meeting those criteria, are shown in Table 22. We selected only the houses that had the most common characteristics because we wanted their average energy use to correspond to the default house characteristics for that region (to provide internal consistency within the HES model).

We then tabulated the mean energy consumption by end-use and fuel, for each of the 45 climate regions. Two of the regions—Hawaii and Alaska—contained no matching housing units, so default energy bills are not available for ZIP codes in these states. Three of the other climate regions—in Oregon and Vermont—had fewer than ten RECS housing units assigned to them, but we still use the data for those regions because the values look reasonable when compared to nearby climate regions. The final consumption values are shown in Appendix B, Table B-1.

**Table 22. Heating and Cooling Characteristics Used to Select RECS Sub-Set**

<b>Climate Region (Representative city)</b>	<b>Heating Fuel</b>	<b>Water Heating Fuel</b>	<b>Central Cooling?</b>	<b>Number of Housing Units</b>	<b>Number of RECS records</b>
Albuquerque, NM	Piped Gas	Piped Gas	YES	222,553	15
Atlanta, GA	Piped Gas	Piped Gas	YES	529,746	48
Birmingham, AL	Piped Gas	Piped Gas	YES	275,251	22
Bismarck ND	Piped Gas	Piped Gas	NO	74,247	5
Boise, ID	Piped Gas	Piped Gas	.	124,663	12
Boston, MA	Fuel Oil	Fuel Oil	NO	405,480	42
Brownsville, TX	Piped Gas	Piped Gas	YES	742,326	54
Buffalo, NY	Piped Gas	Piped Gas	YES	970,285	73
Burlington, VT	Fuel Oil	Fuel Oil	.	58,268	6
Charleston, SC	Electricity	Electricity	YES	235,895	18
Cheyenne, WY	Piped Gas	.	.	148,868	13
Chicago, IL	Piped Gas	Piped Gas	YES	1,307,663	76
Cincinnati, OH	Electricity	Electricity	YES	301,264	30
Denver, CO	Piped Gas	Piped Gas	.	188,607	12
El Paso, TX	Piped Gas	Piped Gas	YES	205,810	18
Fort Worth, TX	Piped Gas	Piped Gas	YES	551,766	45
Fresno, CA	Piped Gas	Piped Gas	YES	609,709	40
Great Falls, MT	Piped Gas	.	.	148,868	13
Jacksonville, FL	Electricity	Electricity	YES	1,429,479	101
Kansas City, KS	Piped Gas	Piped Gas	YES	1,069,328	89
Lake Charles, LA	Piped Gas	Piped Gas	YES	742,326	54
Las Vegas, NV	Electricity	Electricity	YES	159,050	12
Los Angeles, CA	Piped Gas	Piped Gas	YES	438,549	28
Medford, OR	.	.	.	193,184	9
Memphis, TN	Piped Gas	Piped Gas	YES	281,108	17
Miami, FL	Electricity	Electricity	YES	816,844	64
Minneapolis, MN	Piped Gas	Piped Gas	YES	1,170,144	88
Nashville, TN	Piped Gas	Piped Gas	YES	610,090	64
New York, NY	Piped Gas	Piped Gas	YES	264,659	12
Oklahoma City, OK	Piped Gas	Piped Gas	YES	883,018	65
Omaha, NE	Piped Gas	.	.	190,684	12
Philadelphia, PA	Electricity	Electricity	YES	815,580	63
Phoenix, AZ	Electricity	Electricity	YES	159,050	12
Pittsburgh, PA	Piped Gas	Piped Gas	YES	1,712,066	105
Portland, ME	.	.	.	149,716	15
Portland, OR	.	.	.	193,184	9
Reno, NV	.	.	.	292,802	19
Salt Lake City, UT	.	.	.	292,802	19

San Antonio, TX	Piped Gas	Piped Gas	YES	415,925	21
San Diego, CA	Piped Gas	Piped Gas	YES	359,294	20
San Francisco, CA	Piped Gas	Piped Gas	YES	346,907	16
Seattle, WA	.	.	.	178,797	13
Washington, DC	Electricity	Electricity	YES	512,436	44

#### **4.4 Bill Savings in Typical Houses due to Energy Efficiency Upgrades**

In order to provide users an idea of how much they could potentially save on their energy bills, we have estimated technical savings potentials for typical houses in U.S. regions. These estimates of savings potential are applied to the average existing energy bills by climate region, as described in the previous section.

To estimate the potential savings, we selected a single house from 1990 RECS sample to represent each census division. These houses were selected such that their utility bills for were within 10% of the median value in each census division, and they had the heating and cooling equipment that was most common in that census division. These selected houses are single-family detached, with floor area ranging from 1100 to 2900 square feet. 1990 RECS utility bill data were inflated to 1995 dollars using the Consumer Price Indices for electricity, piped gas, and fuel oil. The characteristics of the selected houses are shown in Table 23.

We then estimated the utility bills for these houses, assuming that “best available” technology were applied to the building shell and the equipment contained in that house (according to the RECS survey). Best available technology is generally defined as the most efficient products on the market. The savings estimates are based on several sources, including an LBL Supply curves analysis (Koomey et al. 1991) and unpublished updates to that analysis; the U.S. DOE Water Heater standards analysis (U.S. DOE 1993); a U.S. EPA analysis of space conditioning efficiency improvements (L’Ecuyer et al. 1993); the Honeywell Thermostat Energy Savings Estimator program; Mark Modera, LBL, personal communication; and model directories from the Air conditioning and Refrigeration Institute, Gas Appliance Manufacturers Association, and the California Energy Commission (CEC). The resulting savings factors are shown in Table 24. For lighting, we assumed 50% savings are achievable with a combination of compact fluorescent lamps and outdoor lighting controls.

**Table 23. Estimated Utility Bills After Switching to ENERGY STAR or Best Available Technology**

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1995 \$	Baseline Bill (\$/year)					
<input type="checkbox"/>					Water Heat Fuel	Total Utility Bill	Space Heat	Space Cool	Water Heat	Appl-iances	Total Bill
Census Division	City	Heat Fuel	CAC #	RAC	Fuel						
New England	Worcester, MA	fuel oil	no	1	fuel oil	\$1,621	\$728	\$24	\$162	\$707	\$1,621
Mid Atlantic	Philadelphia, PA	natural gas	no	2	natural gas	\$1,891	\$695	\$201	\$212	\$784	\$1,891
East North Central	Springfield, IL	natural gas	no	0	natural gas	\$1,783	\$686	\$0	\$302	\$794	\$1,783
West North Central	Minneapolis, MN	natural gas	yes	0	natural gas	\$1,023	\$463	\$73	\$127	\$360	\$1,023
South Atlantic	Charleston, SC	electricity	yes	0	electricity	\$1,073	\$134	\$391	\$121	\$427	\$1,073
East South Central	Nashville, TN	electricity	yes	0	electricity	\$1,266	\$316	\$234	\$238	\$478	\$1,266
West South Central	Dallas, TX	natural gas	yes	0	natural gas	\$1,312	\$297	\$454	\$113	\$448	\$1,312
Mountain North	Denver, CO	natural gas	no	0	natural gas	\$1,301	\$459	\$0	\$142	\$700	\$1,301
Mountain South	Phoenix, AZ	electricity	yes	1	electricity	\$1,054	\$109	\$334	\$152	\$458	\$1,054
Pacific North	Seattle, WA	electricity	no	0	electricity	\$998	\$577	\$0	\$97	\$323	\$998
Pacific South	Los Angeles, CA	natural gas	yes	0	natural gas	\$1,058	\$130	\$305	\$59	\$564	\$1,058

**Table 24. Estimated Utility Bill Savings After Switching to ENERGY STAR or Best Available Technology**

<input type="checkbox"/>	% Bill Savings for Energy-Efficient House				
<input type="checkbox"/>	Space Heat	Space Cool	Water Heat	Appl-iances	Total Bill
Census Division					
New England	63%	33%	50%	35%	49%
Mid Atlantic	66%	33%	50%	33%	47%
East North Central	66%	62%	50%	33%	49%
West North Central	66%	59%	50%	34%	52%
South Atlantic	65%	62%	43%	35%	50%
East South Central	65%	62%	43%	35%	49%
West South Central	67%	62%	50%	35%	53%
Mountain North	66%	62%	50%	35%	48%
Mountain South	65%	62%	43%	35%	48%
Pacific North	65%	62%	43%	35%	63%
Pacific South	67%	62%	50%	34%	47%

#### 4.5 Default Energy Prices

When users first enter the Home Energy Saver site, they are assigned default energy prices based on the state in which their ZIP code is located. These default energy prices are the most recent available state averages from either 2002 (for electricity and natural gas) or 2000 (for LPG and fuel oil), summarized in Table 25. All energy price data are from the U.S. DOE's Energy Information Administration (US DOE 2000b, 2003a, 2003b).

**Table 25. Default Energy Prices**

State	Electricity (2002\$/kWh)	Natural Gas (2002\$/therm)	LPG (2000\$/gallon)	Fuel Oil (2000\$/gallon)
Alabama	0.071	1.210	1.407	1.158
Alaska	0.121	0.449	1.689	1.337
Arizona	0.081	1.352	1.455	0.999
Arkansas	0.073	0.929	1.343	1.165
California	0.122	0.715	1.487	1.494
Colorado	0.073	0.646	1.150	1.286
Connecticut	0.110	1.208	1.707	1.369
Delaware	0.087	1.247	1.506	1.270
Florida	0.082	1.478	1.760	1.374
Georgia	0.076	1.142	1.473	1.349
Guam	0.123	1.649	1.545	1.007
Hawaii	0.153	2.309	2.705	1.449
Idaho	0.066	0.854	1.204	1.229
Illinois	0.084	0.749	1.091	1.164
Indiana	0.069	0.819	1.235	1.268
Iowa	0.083	0.870	0.882	1.395
Kansas	0.075	0.955	0.979	1.495
Kentucky	0.057	0.872	1.344	1.263
Louisiana	0.071	0.853	1.468	1.158
Maine	0.133	1.210	1.549	1.365
Maryland	0.077	1.110	1.666	1.419
Massachusetts	0.109	1.015	1.674	1.337
Michigan	0.084	0.698	1.174	1.334
Minnesota	0.075	0.690	1.072	1.232
Mississippi	0.072	0.784	1.449	1.191
Missouri	0.070	0.940	1.045	1.295
Montana	0.073	0.551	1.066	1.164
Nebraska	0.067	0.721	0.917	1.104
Nevada	0.095	1.024	1.420	1.484
New Hampshire	0.120	1.053	1.386	1.282
New Jersey	0.104	0.747	1.767	1.488
New Mexico	0.086	0.752	1.228	1.169
New York	0.134	1.066	1.620	1.499
North Carolina	0.082	1.124	1.443	1.416

North Dakota	0.065	0.563	0.990	1.251
Ohio	0.082	0.812	1.286	1.282
Oklahoma	0.068	0.862	1.087	1.245
Oregon	0.071	1.108	1.345	1.367
Pennsylvania	0.097	1.075	1.591	1.297
Puerto Rico	0.123	1.649	1.545	1.007
Rhode Island	0.102	1.242	1.887	1.347
South Carolina	0.077	1.060	1.498	1.478
South Dakota	0.075	0.770	0.947	1.240
Tennessee	0.064	0.889	1.392	1.512
Texas	0.082	0.848	1.411	1.183
Utah	0.067	0.664	1.279	1.219
Vermont	0.128	1.132	1.458	1.318
Virginia	0.078	1.172	1.584	1.313
Virgin Islands	0.123	1.649	1.545	1.007
Washington	0.063	0.960	1.388	1.539
Washington DC	0.081	1.172	1.649	1.068
West Virginia	0.063	0.662	1.224	1.224
Wisconsin	0.082	0.773	1.059	1.230
Wyoming	0.071	0.600	1.065	1.211

Source: (USDOE 2003a) (USDOE 2003b) (USDOE 2000b) (USDOE 2000b)

#### 4.6 Carbon emissions factors

One of the output reports available in HES is the annual CO<sub>2</sub> emissions caused by the user's household energy consumption. To estimate CO<sub>2</sub> emissions, we use regional emission factors for electricity, and national emission factors for fuel-fired appliances and equipment. For electricity, we developed regional emissions factors using total emissions for fossil steam generation units (US DOE 1996), divided by net generation in each census division.<sup>4</sup> We then added 8% transmission and distribution losses. Finally, we scaled up to account for the additional generation (roughly 2% nationally, but different regionally) that is associated with combustion turbines and internal combustion engines. This approach assumes that the combustion turbines and IC engines have, on average, the same emissions per kWh as the other fossil-steam plants. The resulting values are annual averages for all electricity generated within that region. The resulting emission factors are shown in Table 26.

**Table 26. Electricity carbon emission factors**

Census Division	Carbon emissions (lb. CO <sub>2</sub> /kWh.e)
New England	0.91
Middle Atlantic	1.13
East North Central	1.71
West North Central	1.90
South Atlantic	1.39

<sup>4</sup> This methodology accounts for zero-emission generation from hydro, nuclear, and renewables.

East South Central	1.69
West South Central	1.63
Mountain North	1.98
Mountain South	1.46
Pacific North	0.23
Pacific South	0.48
Total US	1.45
Notes:	
1. Mountain South region includes Arizona and New Mexico. Mountain North region includes all other states in the Mountain census division.	
2. Pacific South region includes California and Hawaii. Pacific North region includes all other states in the Pacific census division.	

For fuel-fired appliances, we used CO<sub>2</sub> emission factors from two different sources, depending on the fuel type. Natural gas and fuel oil emission factors are derived from U.S. DOE (1994), while the LPG emission factor is from U.S. DOE (1996).

**Table 27. Direct carbon emissions from residential natural gas and oil combustion**

Fuel	lb. CO <sub>2</sub> /MBtu
Natural gas	116.83
LPG	137.26
Distillate oil	161.08

## 5. Energy Consumption Reports

### 5.1 Summary by End Use

The energy consumed by devices in each of the major enduse categories (Heating, Cooling, Water Heating, Major Appliances, Small Appliances and Lighting) is summed by utility fuel (Equation 29) and presented in three forms, as an annual bill, as energy consumed and as pollution, in the form of carbon emissions. Some enduses have subdivisions that can also be presented to the user. This information is shown when the users has changed the inputs in the more detailed area. For example, if the user doesn't customize the inputs for Lighting, only one number, Annual Lighting Consumption will be shown. If the user gives general information about the lighting in each room of their house, then the information shown will include summaries of consumption at the room level. If a user goes further to specify actual fixtures in the various rooms, the summary report for Lighting will show this fixture level, as well as summed consumption by room and for the entire house. subdivisions for each enduse. For a list of the devices in each enduse, see the associated calculation section above.

$$UEC_{e,f} = \sum_{d=1}^n UEC_{e,d,f} \quad \text{Equation 29}$$

where

UEC = Energy consumption

d = Device

e = Enduse category

f = fuel in utility units (kWh, therms, gallons<sub>lpg, fuel oil</sub>)

To arrive at the final bill and pollution for each enduse, the energy consumptions for each fuel are multiplied by the price and emissions factor for each fuel (Equations 30 and 31). These values are summed across all fuel to get the enduse bill and pollution.

$$bill_e = \sum_{f=1}^n (UEC_{e,f} * p_f) \quad \text{Equation 30}$$

where

UEC = Energy consumption

bill = annual bill (dollars)

e = Enduse category

p = energy price (dollars)

f = fuel in utility units (kWh, therms, gallons<sub>lpg, fuel oil</sub>)

$$pollution_e = \sum_{f=1}^n (UEC_{e,f} * c_f) \quad \text{Equation 31}$$

where

UEC = Energy consumption

pollution = annual pollution emissions (lbs/C)

e = Enduse category

c = emissions factor (lbs/C)

f = fuel in utility units (kWh, therms, gallons<sub>lpg, fuel oil</sub>)

Total house values for energy, bill and pollution emissions are calculated by summing across enduses.

## 6. Conclusions

The Home Energy Saver incorporates the results and methods of a wide variety of building energy research performed over the years at LBNL, including the linkage to DOE-2, a state of the art energy simulation engine with a steep learning curve. It operates on an array of computer hardware and software, including enterprise level applications such as Oracle. The ability to access the Home Energy Saver as a web site allows the general consumer to take advantage of this experience and infrastructure at no cost to the individual, and without any specialized training.

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## Appendix A. Default House Characteristics

**Table A-1. Characteristics based on Census Division**

	New England	Mid Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
Census Division	1	2	3	4	5	6	7	8	9
Year	1955	1957	1959	1951	1970	1967	1969	1965	1956
Stories	2	2	2	1	1	1	1	1	1
Foundation	Conditioned Basement	Conditioned Basement	Conditioned Basement	Conditioned Basement	Slab	Vented Crawlspace	Slab	Slab	Slab
Heating Equipment	Oil Boiler	Gas Furnace	Gas Furnace	Gas Furnace	Electric Heat Pump	Gas Furnace	Gas Furnace	Gas Furnace	Gas Furnace
Heating Equipment Efficiency	80	78	78	78	7	78	78	78	78
Cooling Equipment	None	Central Air Conditioning	Central Air Conditioning	Central Air Conditioning	Electric Heat Pump	Central Air Conditioning	Central Air Conditioning	None	None
Cooling Equipment Efficiency	0	9.5	9.5	9.5	9.5	9.5	9.5	0	0
Adult at Home during Day	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Water Heater Fuel	Oil	Gas	Gas	Gas	Electricity	Electricity	Gas	Gas	Gas
Energy Factor	0.54	0.54	0.54	0.54	0.86	0.86	0.54	0.54	0.54
Recovery Efficiency	0.76	0.76	0.76	0.76	0.98	0.98	0.76	0.76	0.76
Rated Input	0.65	38000	38000	38000	4.5	4.5	38000	38000	38000
Water Heater Tank Size	32	40	40	40	50	50	40	40	40
Year First Refrigerator was Purchased	1990	1991	1991	1990	1991	1991	1990	1990	1991
Have Dishwasher	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes
Type of Window (window type is assumed to be the same on all sides of house)	Double paned, Clear, Alum. spacer, Wood Frame	Double paned, Clear, Alum. spacer, Wood Frame	Double paned, Clear, Alum. spacer, Wood Frame	Single paned, Clear, No spacer, Wood frame	Single paned, Clear, No spacer, Wood frame	Single paned, Clear, No spacer, Alum. frame	Single paned, Clear, No spacer, Alum. frame	Single paned, Clear, No spacer, Alum. frame	Single paned, Clear, No spacer, Alum. frame
Presence of Ceiling Fan	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Number of Ceiling Fans	0	1	1	1	2	1	2	0	0
Presence of Portable Fans	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes
Number of portable fans	2	2	2	2	0	0	0	2	2

**Table A-2 National Default Housing Characteristics**

<b>Default Characteristic</b>	<b>Value</b>	<b>Unit</b>
Number of Occupants aged 0 to 5	0	<input type="checkbox"/>
Number of Occupants aged 6 to 13	1	<input type="checkbox"/>
Number of Occupants aged 14 to 64	2	<input type="checkbox"/>
Number of Occupants aged 65 and older	0	<input type="checkbox"/>
Thermostat setting of Water Heater	130	deg. F.
Location of Water Heater	garage	<input type="checkbox"/>
Pay for Water Heating Fuel	Yes	<input type="checkbox"/>
Dishwasher Loads per week	4	loads/week
Have Clothes Washer	Yes	<input type="checkbox"/>
Clothes Washer Loads washed in Hot Wash/Warm Rinse	2	loads/week
Clothes Washer Loads washed in Hot Wash/Cold Rinse	0	loads/week
Clothes Washer Loads washed in Warm Wash/Warm Rinse	3	loads/week
Clothes Washer Loads washed in Warm Wash/Cold Rinse	2	loads/week
Clothes Washer Loads washed in Cold Wash/Cold Rinse	0	loads/week
<input type="checkbox"/>		<input type="checkbox"/>
First Refrigerator Model	General	<input type="checkbox"/>
First Refrigerator Year	1986	<input type="checkbox"/>
First Refrigerator Size	17	cubic feet
Second Refrigerator Model	None	<input type="checkbox"/>
Second Refrigerator Year	0	<input type="checkbox"/>
Second Refrigerator Size	0	cubic feet
Third Refrigerator Model	None	<input type="checkbox"/>
Third Refrigerator Year	0	<input type="checkbox"/>
Third Refrigerator Size	0	cubic feet
First Freezer Model	None	<input type="checkbox"/>
First Freezer Year	0	<input type="checkbox"/>
First Freezer Size	0	cubic feet
Second Freezer Model	None	<input type="checkbox"/>
Second Freezer Year	0	<input type="checkbox"/>
Second Freezer Size	0	cubic feet

Clothes Dryer Loads per week	7	loads/week
Clothes Dryer Fuel	Electricity	<input type="checkbox"/>
Stove Fuel	Electricity	<input type="checkbox"/>
Oven Fuel	Electricity	<input type="checkbox"/>
Hours Stove Used per week	1	hour
Hours Oven Used per Week	2	hours
Does Stove have a Pilot Light	No	<input type="checkbox"/>
Does Oven have a Pilot Light	No	<input type="checkbox"/>
<input type="checkbox"/>		<input type="checkbox"/>
Lighting consumption in Kitchen	218	kWh
Lighting consumption in Dining Room	136	kWh
Lighting consumption in Living Room	109	kWh
Lighting consumption in Family Room	77	kWh
Lighting consumption in Master Bedroom	81	kWh
Lighting consumption in Bedroom	73	kWh
Lighting consumption in Closet	0	kWh
Lighting consumption in Bathroom	192	kWh
Lighting consumption in Hall	98	kWh
Lighting consumption in Utility Room	0	kWh
Lighting consumption in Garage	71	kWh
Lighting consumption in Outdoor Fixtures	231	kWh
Lighting consumption in Other Rooms	0	kWh
Number of Lighting Fixtures in Kitchen	2	fixtures
Number of Lighting Fixtures in Dining Room	1	fixtures
Number of Lighting Fixtures in Living Room	3	fixtures
Number of Lighting Fixtures in Family Room	1	fixtures
Number of Lighting Fixtures in Master Bedroom	2	fixtures
Number of Lighting Fixtures in Bedroom	2	fixtures
Number of Lighting Fixtures in Closet	0	fixtures
Number of Lighting Fixtures in Bathroom	2	fixtures
Number of Lighting Fixtures in Hall	2	fixtures
Number of Lighting Fixtures in Utility Room	0	fixtures

Number of Lighting Fixtures in Garage	1	fixtures
Number of Lighting Fixtures Outdoors	2	fixtures
Number of Lighting Fixtures in Other Rooms	0	fixtures

## Appendix B. Default Energy Consumption

**Table B-1 Average Residential End-Use Energy Consumption by Region**

Climate Region (Representative city)	Space Heating (Mbtu)			Electric Space	Water Heating (Mbtu)			Appliances (Mbtu)		Miscellaneous
	Electricity	Natural Gas	Fuel Oil	Cooling (Mbtu)	Electricity	Natural Gas	Fuel Oil	Electricity	Natural Gas	Electricity (Mbtu)
Albuquerque, NM	0	67	0	8	0	28	0	13	3	13
Atlanta, GA	0	63	0	15	0	24	0	16	4	17
Birmingham, AL	0	59	0	17	0	32	0	19	4	22
Bismarck ND	0	139	0	0	0	28	0	10	4	11
Boise, ID	0	90	0	3	0	32	0	11	1	15
Boston, MA	0	0	105	0	0	0	32	10	1	15
Brownsville, TX	0	37	0	16	0	21	0	15	5	18
Buffalo, NY	0	101	0	5	0	28	0	10	4	15
Burlington, VT	0	0	118	0	0	0	32	9	0	11
Charleston, SC	12	0	0	11	8	0	0	12	1	14
Cheyenne, WY	0	87	0	0	11	0	0	11	0	14
Chicago, IL	0	91	0	6	0	26	0	9	6	15
Cincinnati, OH	29	0	0	12	14	0	0	15	0	20
Denver, CO	0	72	0	5	0	24	0	12	3	13
El Paso, TX	0	44	0	16	0	23	0	15	3	19
Fort Worth, TX	0	60	0	20	0	19	0	18	8	23
Fresno, CA	0	36	0	5	0	19	0	9	3	11
Great Falls, MT	0	87	0	0	0	34	0	11	0	14
Jacksonville, FL	9	0	0	12	7	0	0	11	0	14
Kansas City, KS	0	102	0	9	0	27	0	12	3	15
Lake Charles, LA	0	37	0	16	0	21	0	15	5	18
Las Vegas, NV	9	0	0	15	8	0	0	12	0	14
Los Angeles, CA	0	28	0	7	0	21	0	9	5	14
Medford, OR	8	15	17	2	0	23	0	13	1	18
Memphis, TN	0	54	0	11	0	25	0	11	6	13
Miami, FL	6	0	0	18	7	0	0	14	0	20
Minneapolis, MN	0	89	0	4	0	26	0	11	3	16
Nashville, TN	0	77	0	11	0	26	0	14	4	17

New York, NY	0	111	0	12	0	36	0	12	14	22
Oklahoma City, OK	0	78	0	13	0	31	0	14	6	17
Omaha, NE	0	99	0	6	0	21	0	11	2	13
Philadelphia, PA	23	0	2	9	11	0	0	11	0	14
Phoenix, AZ	9	0	0	15	8	0	0	12	0	14
Pittsburgh, PA	0	101	0	8	0	29	0	10	7	16
Portland, ME	4	0	50	3	0	0	34	10	0	13
Portland, OR	8	15	17	0	0	23	0	13	1	18
Reno, NV	5	24	6	2	0	18	0	10	5	16
Salt Lake City, UT	5	24	6	2	0	18	0	10	5	16
San Antonio, TX	0	42	0	19	0	23	0	16	10	22
San Diego, CA	0	30	0	4	0	19	0	9	10	18
San Francisco, CA	0	43	0	3	0	22	0	7	3	10
Seattle, WA	20	35	8	3	0	34	0	13	2	19
Washington, DC	26	0	0	11	11	0	0	14	0	16

Notes:

1) Source: 1993 RECS

Averages are for single-family houses with the characteristics described in Table 18.

## Appendix C. Local Climate Parameters

**Table C-1. Climate Parameters Associated to Weather Locations**

State	City	Dry Bulb to Wet Bulb ratio <sup>5</sup>	Duct Factor	Heating Dry Bulb Temperature	Cooling Dry Bulb Temperature	Total Annual Room Air Conditioner Compressor Hours	Room Air Conditioner Use (hours/day) (days/yr)	
Alaska	Anchorage	1.196721311	0.999009823	0	85	16	2	8
Alaska	Annette	1.183333333	0.997864512	20	85	11	2	6
Alaska	Barrow	1.0625	1	-30	85	0	2	0
Alaska	Bethel	1.220338983	0.999214451	-20	85	11	2	5
Alaska	Bettles	1.262295082	0.994467163	-30	85	36	2	18
Alaska	Big Delta	1.271186441	0.994840925	-30	85	32	2	16
Alaska	Cold Bay	1.072727273	1	10	85	0	2	0
Alaska	Fairbanks	1.295081967	0.989521509	-30	85	61	2	30
Alaska	Gulkana	1.271186441	1	-30	85	21	2	11
Alaska	King Salmon	1.183333333	0.999775209	-20	85	9	2	4
Alaska	Kodiak	1.13559322	0.998850356	10	85	3	2	1
Alaska	Kotzebue	1.169491525	0.998686116	-30	85	5	2	2
Alaska	McGrath	1.229508197	0.995132581	-30	85	21	2	11
Alaska	Nome	1.155172414	1	-20	85	2	2	1
Alaska	St. Paul Island	1.020408163	1	10	85	0	2	0
Alaska	Talkeetna	1.2	0.999333093	-20	85	21	2	10
Alaska	Yakutat	1.125	1	0	85	1	2	1
Alabama	Birmingham	1.192307692	0.247257	20	95	997	12	83
Alabama	Huntsville	1.220779221	0.296609144	10	95	957	12	80
Alabama	Mobile	1.202531646	0.116946685	30	95	1310	12	109
Alabama	Montgomery	1.2125	0.162166981	30	100	1162	14	83

<sup>5</sup> DB/WB ratio is the ratio of dry-bulb to wet-bulb temperature at the cooling design-day conditions. It is intended as a relative indicator of a climate's humidity during the cooling season.

Arkansas	Fort Smith	1.265822785	0.255740195	20	100	978	13	75
Arkansas	Little Rock	1.240506329	0.242700686	10	100	1009	13	78
Arizona	Flagstaff	1.370967742	0.931595449	0	85	151	5	30
Arizona	Phoenix	1.5	0.055493769	40	110	1648	12	137
Arizona	Prescott	1.439393939	0.487931266	20	95	603	7	86
Arizona	Tucson	1.402777778	0.098499568	30	105	1447	12	121
California	Arcata	1.114754098	0.996544761	30	85	9	2	4
California	Bakersfield	1.430555556	0.147032383	40	105	831	11	76
California	China Lake	1.573529412	0.151129461	30	110	1088	11	99
California	Daggett	1.486111111	0.101769658	30	110	1059	12	88
California	El Centro	1.454545455	0.048545885	40	110	1562	13	120
California	El Toro	1.295774648	0.278824868	40	95	210	10	21
California	Fresno	1.416666667	0.211580246	30	105	831	12	69
California	Long Beach	1.225352113	0.212439669	40	90	205	9	23
California	Los Angeles	1.15942029	0.348218631	50	85	122	9	14
California	Mt Shasta	1.373134328	0.671054834	20	95	314	6	52
California	Oakland	1.203125	0.881102013	40	85	73	8	9
California	Pasadena	1.291666667	0.241473541	40	95	259	10	26
California	Red Bluff	1.5	0.232430988	30	110	1172	12	98
California	Riverside	1.436619718	0.243356089	30	105	660	11	60
California	Sacramento	1.414285714	0.32177679	40	100	724	10	72
California	Santa Rosa	1.394366197	0.403603965	30	100	701	10	70
California	San Diego	1.214285714	0.214329328	50	85	69	8	9
California	San Francisco	1.296875	0.901823244	40	85	84	6	14
California	Santa Maria	1.222222222	0.912290826	30	85	19	8	2
California	Sunnyvale	1.25	0.73485973	40	85	218	7	31
Colorado	Alamosa	1.440677966	0.969799166	-10	85	204	3	68
Colorado	Boulder	1.424242424	0.652142713	0	95	412	6	69
Colorado	Colorado Springs	1.451612903	0.756063615	0	90	381	5	76
Colorado	Eagle	1.426229508	0.95809304	0	90	282	5	56
Colorado	Grand Junction	1.484375	0.490593931	10	95	684	6	114

Colorado	Pueblo	1.426470588	0.526418645	0	100	668	9	74
Connecticut	Bridgeport	1.144736842	0.57981672	20	90	262	4	66
Connecticut	Hartford	1.192307692	0.620454701	0	95	285	6	48
Delaware	Wilmington	1.141025641	0.47678874	20	90	484	11	44
Florida	Daytona Beach	1.179487179	0.058270206	30	95	1281	12	107
Florida	Jacksonville	1.172839506	0.095059102	30	95	1198	13	92
Florida	Key West	1.139240506	0.002526185	60	90	2879	11	262
Florida	Miami	1.139240506	0.006595124	50	90	2031	11	185
Florida	Tallahassee	1.15	0.126190217	30	95	1110	13	85
Florida	Tampa	1.17721519	0.039293763	40	95	1677	12	140
Florida	West Palm Beach	1.1375	0.011916615	40	95	1857	13	143
Georgia	Athens	1.194805195	0.252475085	20	95	829	12	69
Georgia	Atlanta	1.181818182	0.271459832	20	95	802	12	67
Georgia	Augusta	1.192307692	0.239822302	20	95	1023	12	85
Georgia	Columbus	1.205128205	0.17497912	30	95	977	12	81
Georgia	Macon	1.220779221	0.179451474	20	95	1008	12	84
Georgia	Savannah	1.17721519	0.141942714	30	95	1093	12	91
Hawaii	Hilo	1.118421053	0	60	85	1445	10	144
Hawaii	Honolulu	1.189189189	0	60	90	2016	10	202
Hawaii	Kahului	1.157894737	0.000126116	60	90	1852	11	168
Hawaii	Lihue	1.133333333	0	60	85	1814	9	202
Iowa	Des Moines	1.220779221	0.581854697	0	95	493	6	82
Iowa	Mason City	1.173333333	0.758581033	-10	90	374	4	94
Iowa	Sioux City	1.220779221	0.607090676	0	95	527	6	88
Iowa	Waterloo	1.157894737	0.705876891	-10	90	402	4	101
Idaho	Boise	1.476923077	0.627489734	10	100	526	8	66
Idaho	Pocatello	1.476190476	0.803580345	0	95	445	6	74
Illinois	Chicago	1.181818182	0.625940087	0	95	426	6	71
Illinois	Moline	1.220779221	0.581284233	0	95	529	6	88
Illinois	Peoria	1.179487179	0.58224755	0	95	522	6	87
Illinois	Rockford	1.128205128	0.682047457	0	90	368	4	92

Illinois	Springfield	1.192307692	0.49423345	0	95	651	12	54
Indiana	Evansville	1.192307692	0.418317157	0	95	782	12	65
Indiana	Fort Wayne	1.168831169	0.654152051	0	90	491	4	123
Indiana	Indianapolis	1.181818182	0.548441213	0	95	548	12	46
Indiana	South Bend	1.153846154	0.611230712	10	90	413	4	103
Kansas	Dodge City	1.351351351	0.431436016	0	100	758	11	69
Kansas	Goodland	1.4	0.591430738	0	100	599	10	60
Kansas	Topeka	1.202531646	0.44680302	0	95	631	12	53
Kansas	Wichita	1.298701299	0.375232443	0	100	723	12	60
Kentucky	Covington	1.168831169	0.500054651	10	90	593	11	54
Kentucky	Lexington	1.2	0.49121763	10	90	568	10	57
Kentucky	Louisville	1.166666667	0.398916911	10	95	752	13	58
Louisiana	Baton Rouge	1.17721519	0.116147735	30	95	1253	12	104
Louisiana	Lake Charles	1.15	0.110798438	30	95	1285	13	99
Louisiana	New Orleans	1.1625	0.100744406	30	95	1244	13	96
Louisiana	Shreveport	1.202531646	0.158433926	30	95	1113	12	93
Massachusetts	Boston	1.222222222	0.637236428	10	90	305	4	76
Massachusetts	Worcester	1.131578947	0.776550655	10	90	124	4	31
Maryland	Baltimore	1.189873418	0.457187012	10	95	588	12	49
Maine	Caribou	1.14084507	0.9421713	-10	85	79	2	40
Maine	Portland	1.148648649	0.821117864	0	85	179	2	90
Michigan	Alpena	1.194444444	0.884775357	0	90	149	4	37
Michigan	Detroit	1.155844156	0.697595958	10	90	313	4	78
Michigan	Flint	1.175675676	0.753383547	0	90	230	4	57
Michigan	Grand Rapids	1.175675676	0.732361777	0	90	289	4	72
Michigan	Houghton	1.136986301	0.876642217	-10	85	164	2	82
Michigan	Lansing	1.146666667	0.715765368	0	90	315	4	79
Michigan	Muskegon	1.166666667	0.734783928	10	85	228	2	114
Michigan	Sault Ste. Marie	1.142857143	0.955351005	0	85	99	2	50
Michigan	Traverse City	1.16	0.767661164	0	90	242	4	61
Minnesota	Duluth	1.166666667	0.933933556	-20	85	119	2	60

Minnesota	Int'nl Falls	1.136986301	0.942145711	-20	85	150	2	75
Minnesota	Minneapolis	1.142857143	0.709910823	-10	90	357	4	89
Minnesota	Rochester	1.162162162	0.762093126	-10	90	259	4	65
Minnesota	Saint Cloud	1.157894737	0.808246507	-10	90	247	4	62
Missouri	Columbia	1.230769231	0.448050872	10	100	686	13	53
Missouri	Kansas City	1.189873418	0.40944121	10	95	809	12	67
Missouri	St. Louis	1.202531646	0.404364734	10	95	757	12	63
Missouri	Springfield	1.220779221	0.403670598	0	95	687	12	57
Mississippi	Jackson	1.202531646	0.178691491	30	95	1130	12	94
Mississippi	Meridian	1.189873418	0.201565172	30	95	1021	12	85
Montana	Billings	1.409090909	0.690271954	0	95	391	6	65
Montana	Cut Bank	1.393442623	0.961705229	-10	85	199	2	100
Montana	Glasgow	1.338235294	0.782183376	-20	95	276	6	46
Montana	Great Falls	1.40625	0.805883987	-10	90	309	4	77
Montana	Helena	1.467741935	0.822114419	-10	95	253	6	42
Montana	Kalispell	1.40625	0.938962831	0	90	279	4	70
Montana	Lewistown	1.415384615	0.885967513	-10	95	235	6	39
Montana	Miles City	1.397058824	0.716613235	-10	95	403	6	67
Montana	Missoula	1.4375	0.848324989	-10	95	263	6	44
North Carolina	Asheville	1.205479452	0.539566909	20	90	426	10	43
North Carolina	Cape Hatteras	1.101265823	0.258118062	30	90	721	12	60
North Carolina	Charlotte	1.194805195	0.304882745	20	95	802	12	67
North Carolina	Greensboro	1.166666667	0.393979849	10	95	667	13	51
North Carolina	Raleigh	1.179487179	0.344262692	20	95	667	12	56
North Carolina	Wilmington	1.15	0.216553482	30	95	796	13	61
North Dakota	Bismarck	1.216216216	0.804948188	-20	90	354	4	89
North Dakota	Fargo	1.184210526	0.7632616	-20	90	397	4	99
North Dakota	Minot	1.225352113	0.851326817	-10	90	293	4	73
Nebraska	Grand Island	1.24	0.574178244	0	95	561	6	94
Nebraska	Norfolk	1.266666667	0.572365987	0	95	577	6	96
Nebraska	North Platte	1.315068493	0.630799542	-10	100	502	8	63

Nebraska	Omaha	1.202531646	0.527928552	0	95	527	6	88
Nebraska	Scottsbluff	1.391304348	0.636975202	0	100	485	8	61
New Hampshire	Concord	1.191780822	0.78764102	0	90	345	4	86
New Jersey	Atlantic City	1.205128205	0.530107958	10	95	463	12	39
New Jersey	Newark	1.213333333	0.483899782	10	95	471	6	79
New Mexico	Albuquerque	1.439393939	0.41175504	20	95	790	7	113
New Mexico	Tucumcari	1.420289855	0.346450448	20	100	902	10	90
Nevada	Elko	1.540983607	0.829450518	0	95	349	6	58
Nevada	Ely	1.517241379	0.915378077	0	90	374	4	94
Nevada	Las Vegas	1.507042254	0.126854817	30	110	1439	12	120
Nevada	Reno	1.516129032	0.744781091	10	95	407	6	68
Nevada	Tonopah	1.516129032	0.600264638	20	95	632	6	105
Nevada	Winnemucca	1.546875	0.674574333	10	100	634	8	79
New York	Albany	1.189189189	0.717139615	0	90	319	4	80
New York	Binghamton	1.138888889	0.821770218	0	85	175	2	88
New York	Buffalo	1.178082192	0.71886666	0	90	283	4	71
New York	Massena	1.175675676	0.824336836	-10	90	245	4	61
New York	New York City	1.213333333	0.496824536	10	95	432	6	72
New York	Rochester	1.202702703	0.67845352	0	90	331	4	83
New York	Syracuse	1.157894737	0.738981176	0	90	324	4	81
Ohio	Akron	1.157894737	0.662582089	0	90	319	4	80
Ohio	Cleveland	1.186666667	0.657916021	10	90	395	4	99
Ohio	Columbus	1.16	0.580603061	10	90	570	4	143
Ohio	Dayton	1.175675676	0.617111931	0	90	527	10	53
Ohio	Mansfield	1.173333333	0.638304278	0	90	529	4	132
Ohio	Toledo	1.186666667	0.682794995	0	90	402	4	101
Ohio	Youngstown	1.148648649	0.71539325	0	85	281	2	141
Oklahoma	Oklahoma City	1.269230769	0.289700288	10	100	859	13	66
Oklahoma	Tulsa	1.256410256	0.283970501	10	100	1009	13	78
Oregon	Astoria	1.169230769	0.987038046	30	85	25	2	13
Oregon	Burns	1.435483871	0.82845429	10	90	296	4	74

Oregon	Eugene	1.323529412	0.79804676	30	90	262	4	66
Oregon	Medford	1.449275362	0.582853388	20	100	456	8	57
Oregon	North Bend	1.147540984	0.998890205	40	85	12	2	6
Oregon	Pendleton	1.5	0.600476832	20	100	420	8	53
Oregon	Portland	1.328358209	0.756820717	30	90	174	4	44
Oregon	Redmond	1.451612903	0.870837788	0	90	311	4	78
Oregon	Salem	1.338235294	0.828377711	30	95	253	6	42
Pennsylvania	Allentown	1.175675676	0.612008574	10	90	381	4	95
Pennsylvania	Bradford	1.126760563	0.918044859	0	85	160	2	80
Pennsylvania	Erie	1.133333333	0.743030624	0	85	298	2	149
Pennsylvania	Harrisburg	1.210526316	0.518874486	20	95	503	6	84
Pennsylvania	Philadelphia	1.181818182	0.488720814	20	95	514	12	43
Pennsylvania	Pittsburgh	1.173333333	0.629829575	10	90	371	4	93
Pennsylvania	Wilkes-Barre	1.157894737	0.703582436	0	90	336	4	84
Pennsylvania	Williamsport	1.186666667	0.63768991	10	90	396	4	99
Guam	Agana	1.125	0	60	90	2016	12	168
Puerto Rico	Aguadilla	1.125	0	60	90	3151	12	263
Puerto Rico	Ponce	1.125	0	60	90	3151	12	263
Puerto Rico	San Juan	1.125	0	60	90	3151	12	263
Virgin Islands	Christiansted	1.125	0	60	90	3151	12	263
Rhode Island	Providence	1.186666667	0.656514309	10	90	237	4	59
South Carolina	Charleston	1.192307692	0.17592498	30	95	950	12	79
South Carolina	Columbia	1.230769231	0.220650544	20	100	931	13	72
South Carolina	Greenville	1.194805195	0.30864303	20	95	800	12	67
South Dakota	Huron	1.210526316	0.751340045	-10	95	460	6	77
South Dakota	Pierre	1.364864865	0.638386981	-10	105	459	10	46
South Dakota	Rapid City	1.347826087	0.733107331	-10	95	408	6	68
South Dakota	Sioux Falls	1.289473684	0.657455215	-10	100	436	8	55
Tennessee	Bristol	1.216216216	0.476119339	20	90	598	10	60
Tennessee	Chattanooga	1.230769231	0.302294517	20	100	913	13	70
Tennessee	Knoxville	1.171052632	0.342562865	10	90	767	11	70

Tennessee	Memphis	1.175	0.232016261	20	95	974	13	75
Tennessee	Nashville	1.230769231	0.318996183	10	100	832	13	64
Texas	Abilene	1.351351351	0.180945595	20	100	1165	11	106
Texas	Amarillo	1.357142857	0.411400443	10	95	820	9	91
Texas	Austin	1.246753247	0.096504651	30	100	1375	13	106
Texas	Brownsville	1.175	0.034668635	40	95	1991	13	153
Texas	Corpus Christi	1.185185185	0.049947106	40	100	2150	14	154
Texas	El Paso	1.4	0.19783823	30	100	1204	10	120
Texas	Fort Worth	1.25974026	0.156404406	30	100	1374	13	106
Texas	Houston	1.175	0.096911461	30	95	1308	13	101
Texas	Lubbock	1.338028169	0.299369496	10	95	926	9	103
Texas	Lufkin	1.227848101	0.129599496	30	100	1380	13	106
Texas	Midland	1.388888889	0.209558602	20	100	1240	10	124
Texas	Port Arthur	1.1625	0.100189184	40	95	1217	13	94
Texas	San Angelo	1.351351351	0.191757606	20	100	1493	11	136
Texas	San Antonio	1.246753247	0.102260888	30	100	1351	13	104
Texas	Victoria	1.202531646	0.06875085	40	95	1761	12	147
Texas	Waco	1.282051282	0.137418818	30	100	1399	12	117
Texas	Wichita Falls	1.320512821	0.199253593	20	105	1264	14	90
Utah	Cedar City	1.476190476	0.643614387	0	95	770	6	128
Utah	Salt Lake City	1.507692308	0.509548689	20	100	705	8	88
Virginia	Lynchburg	1.2	0.446805363	10	90	611	10	61
Virginia	Norfolk	1.179487179	0.320229784	20	95	614	12	51
Virginia	Richmond	1.179487179	0.380322018	20	95	693	12	58
Virginia	Roanoke	1.226666667	0.441851459	20	95	617	11	56
DC	Washington	1.194805195	0.493362126	10	95	560	12	47
Vermont	Burlington	1.16	0.790246011	0	90	216	4	54
Washington	Olympia	1.308823529	0.884071949	30	90	115	4	29
Washington	Quillayute	1.19047619	0.993498293	30	85	31	2	15
Washington	Seattle	1.257575758	0.881599318	30	85	105	2	53
Washington	Spokane	1.507936508	0.767837141	0	95	311	6	52

Washington	Yakima	1.382352941	0.738447234	10	95	380	6	63
Wisconsin	Eau Claire	1.157894737	0.762652781	-20	90	303	4	76
Wisconsin	Green Bay	1.162162162	0.795633227	-10	90	235	4	59
Wisconsin	La Crosse	1.171052632	0.706874929	-10	90	348	4	87
Wisconsin	Madison	1.168831169	0.736673886	-10	90	360	4	90
Wisconsin	Milwaukee	1.153846154	0.755439418	0	90	236	4	59
West Virginia	Charleston	1.171052632	0.499159681	10	90	589	11	54
West Virginia	Elkins	1.135135135	0.779808488	0	85	265	9	29
West Virginia	Huntington	1.171052632	0.466723301	10	90	593	11	54
Wyoming	Casper	1.467741935	0.820492688	-10	95	427	6	71
Wyoming	Cheyenne	1.426229508	0.846387621	0	90	285	4	71
Wyoming	Lander	1.451612903	0.802392449	0	90	232	4	58
Wyoming	Rock Springs	1.482758621	0.897871035	0	90	222	4	56
Wyoming	Sheridan	1.409090909	0.796282907	-10	95	406	6	68

## Appendix D. Technical Specification of the Home Energy Saver website

### 1. Hardware

The Home Energy Saver currently operates on a cluster of eleven computers. One computer serves the bulk of the flat html content, two machines act as the application servers, running in parallel to provide redundancy in the event of an outage. A network file server coordinate the transfer of data to and from the DOE-2 servers (a bank of six computers which handle DOE-2 calculations in parallel based on availability and load). Finally user data is stored in a database running on Central LBL servers.

### 2. User interface

#### 2.1. Entry page

The Home Energy Saver has been developed to assist users in making decisions about energy efficiency in their home. It has an extensive cataloged list of on-line information about energy use in the home, as well as the entry point for the calculation engine described in this report. At this point, users can choose to enter their ZIP code and initiate a session, or enter their session number from a previous visit, which will return them to the results of that session.

Figure 1. Entry Page for Home Energy Saver Website

**HOME ENERGY SAVER**  
*Investing in a home on your street could be more profitable than investing on Wall Street.*

The first web-based do-it-yourself energy audit tool.  
**Find Out More!**

**Energy Advisor**  
*Find the best ways to save energy in YOUR home*

Enter your ZIP CODE or Enter Previous Session #

**Go!**

Don't know the ZIP CODE?

**Making It Happen**  
*Find resources to make your home more energy efficient*

Money isn't all you save.  
Visit the ENERGY STAR website for information on energy-efficient products.

**Start Saving Energy in Your Home Today!**  
Try the Home Energy Advisor for a simplified version of the calculator.

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## 2.2. Initial “Simple” Inputs Page with ZIP Code Based Bill

After entering a zip code, the users see the first page, which shows the RECS consumption for a typical house in their area, see Section 4.3 for details on how this average bill was generated. The lower half of the screen shows the questions for the “simple” level of calculation (Figure 2). Users have the choice of calculating the bill for their house, based on those questions, or providing more detail about their house before calculating. By answering the detailed questions (Figure 3), users get results calculated using a house description that more closely matches their house.

Figure 2. Initial “Simple” Inputs Page with ZIP Code Based Bill

**Home Energy Saver** Making It Happen

About HES What's New Energy Librarian Glossary FAQ Search E-mail Help

General Info Heating & Cooling Water Heating Major Appliances Small Appliances Lighting

### Energy Bill for Houses in San Jose, California

Based on the zip code you entered, here is a comparison of the energy costs of an average home and an energy-efficient home in your area.

Category	Average House	Efficient House
Heating	\$350	\$250
Cooling	\$150	\$100
Water Heating	\$150	\$100
Major Appliances	\$150	\$100
Lighting	\$100	\$50
Small Appliances	\$100	\$50
<b>Total</b>	<b>\$1170</b>	<b>\$677</b>

**Potential Savings \$493**

**About the Results**

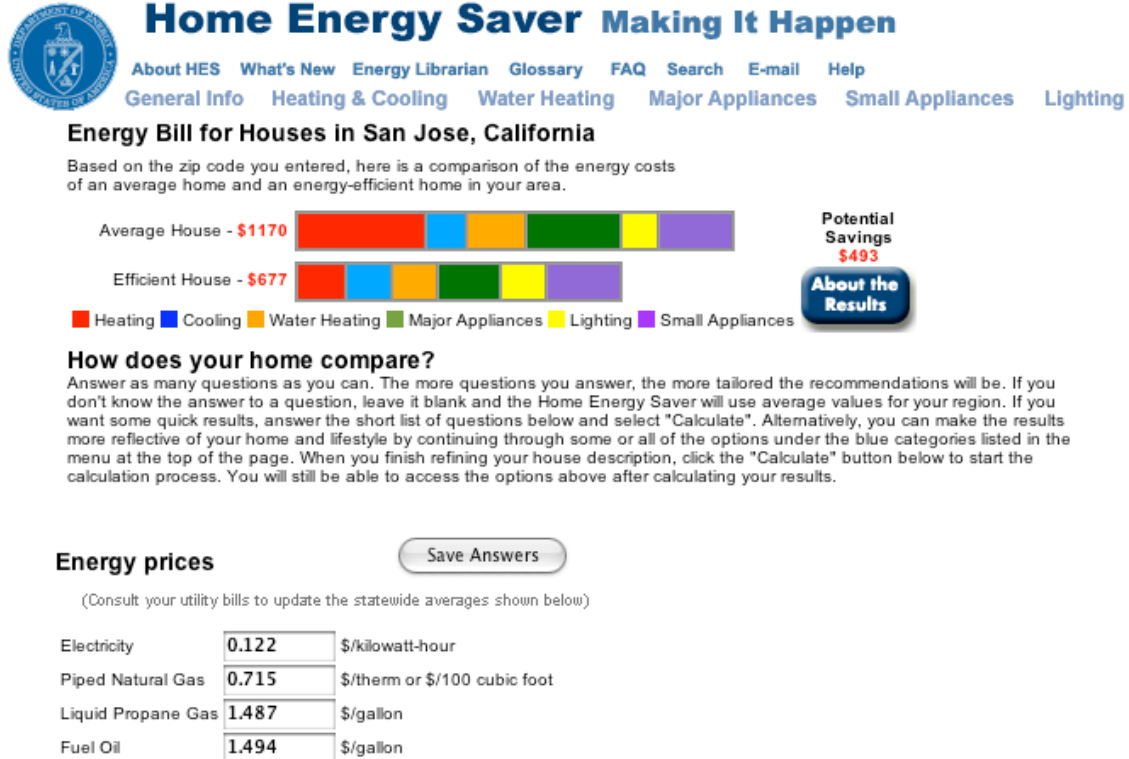
**How does your home compare?**

Answer as many questions as you can. The more questions you answer, the more tailored the recommendations will be. If you don't know the answer to a question, leave it blank and the Home Energy Saver will use average values for your region. If you want some quick results, answer the short list of questions below and select "Calculate". Alternatively, you can make the results more reflective of your home and lifestyle by continuing through some or all of the options under the blue categories listed in the menu at the top of the page. When you finish refining your house description, click the "Calculate" button below to start the calculation process. You will still be able to access the options above after calculating your results.

**Save Answers**

1. Which city has the most similar climate to your house?
2. Year your house was built:
3. What is the conditioned floor area:  sq. ft.
4. How many stories above ground level are there?
5. The front of your house faces:
6. What type of foundation does your house have?

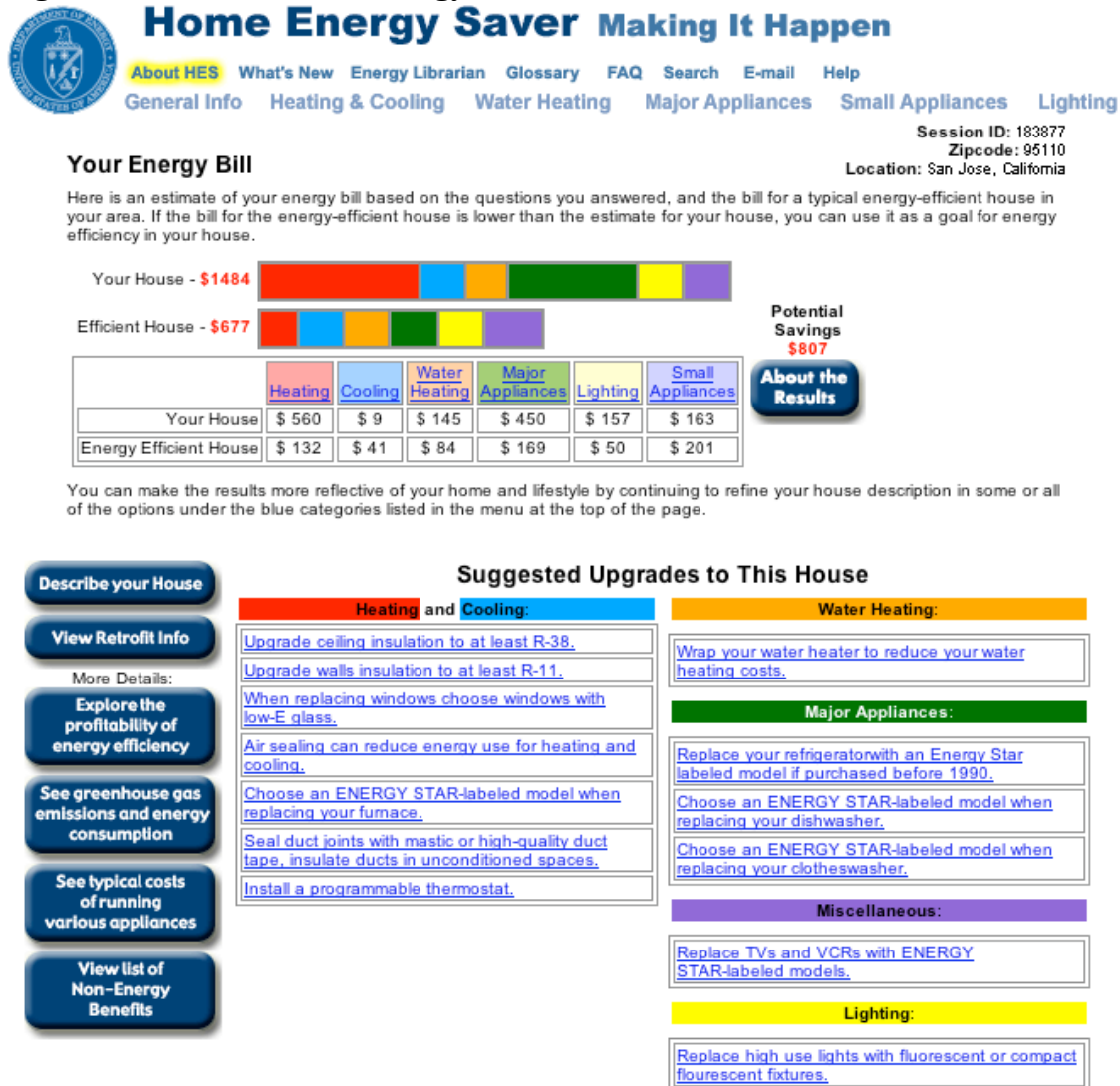
Figure 3. Sample Detailed Input Page (Energy Prices)



### 2.3. Results page

After the energy calculations are complete, users are presented with a new page showing the results of the calculation. The top half of the page now contains results generated from their house description (rather than a typical house in their area). The bottom half of the page shows a list of possible retrofits for their house, based on the current house description, as well as links to other reports about their energy use and information that can help them save energy in their house.

Figure 4. Results of Home Energy Saver Calculation



### **3. Error handling**

#### **3.1 User input validations**

Where appropriate, the user interface is designed with javascript and occasionally server-side input validations to ensure that the answer submitted by the user is valid. There are two main types of javascript validations, the first prevents non-valid characters from being typed into text boxes (e.g. alphabetic characters not allowed in an integer text field), while the second checks the final value against the allowable range (e.g. percentage values must be between 0% and 100%). Additionally in a few instances, there are server side validations that check inputs for more complicated problems (e.g. window area is greater than wall area when framing members and area of doors is included). When an error is noted, a message is displayed to the user, identifying the problem and asking them to correct their inputs.

#### **3.2 Failures in the DOE-2.1 calculation**

On occasion, a dropped network connection or an inappropriate house description can cause the DOE-2 engine to experience failure. The Home Energy Saver has error traps in place to prevent the loss of data in a situation where there is a DOE-2 failure. After the results of the DOE-2 run are returned to the web application, the returned energy consumptions are tested for valid values. If an error is detected, the web application discards the returned values, continuing the calculation with the previous energy consumptions for heating and cooling. If results are not returned from DOE

### **4. Limitations and Advantages of Web-based Energy Modeling**

- State – Unlike a computer based application, the web based environment does not maintain a constant connection between a user and the application. For each new action, the web server must be given information to connect a user with their particular session, in the form of cookies or a session ID. If this information expires, the user is required to start the process over.
- Network Latency and Errors – the internet is a conglomeration of servers, routers and transmission paths that are largely independent of each other. Delays or lack of service in any part can make it appear to a user that our site is unavailable or slow. To a great extent, the internet compensates for outage and bottlenecks by re-routing traffic to areas with greater capacity, but some bottlenecks can't be avoided, such as the link from the user's computer to their ISP.
- User comprehension – energy modeling is a complex process, and has its share of technical language. We've attempted to use common language in parsing inputs and results, but misunderstandings and confusion can still occur. The lack of a trained professional on hand to assist may limit some users experience.
- Additional advantages include ease of distribution, version control, platform independence and the ability to locate computation-intensive simulation engines such as DOE-2 on a central server, rather than requiring users to install and administer them on home personal computers.